PUBLIC WORKS

city county and state

may 1949

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some of the articles in this issue:

Water and Sewage Chemistry and Chemicals
A Complete Text

•

How North Carolina Builds Bituminous Pavements

•

Design for Subsurface Sewage Disposal

•

Street Maintenance Organization

★ ★ ★

Complete Contents Listed on Page 5

YOU NEED BOTH HALVES OF THE SCISSOR

In the CHICAGO Comminutor the cutters and shear bars cut and chop; the channel feeds and holds.

The combination of channel and rotating drum makes the CHICAGO Comminutor the only effective method for cutting and screening sewage solids in the stream.

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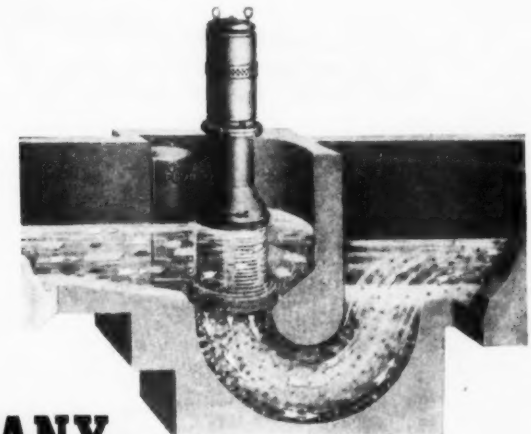
The CHICAGO Comminutor is always placed in an exclusively designed feeder channel. The hydraulic characteristics are such that accumulating solids cannot clog the drum slots; nor can rope-like material jam the drum. Comminution is rapid and positive. Sub-surface screening is continuous and automatic.



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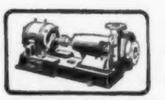

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MAY, 1949

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PUBLIC WORKS

THE ENGINEERING AUTHORITY IN THE CITY-COUNTY FIELD

Edited by
W. A. HARDENBERGH and A. PRESCOTT FOLWELL

MAY, 1949

GENERAL

HIGHWAYS, AIRPORTS AND CONSTRUCTION

SEWERAGE AND REFUSE

WATER SUPPLY AND PURIFICATION

Founded in 1896

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The EDITOR'S PAGE

How to Get More Engineers for Your Organization

There is a widespread need for more engineers; probably young engineers are now more in demand. The Joint Cooperative Committee of the AASHO and the AGC recently gave its views on how to get more young engineers. At the head of the list is better pay, not only for the young engineer, but also for the older engineers; more contacts between state, county and city engineering offices and engineering colleges; more consideration for the living needs for young engineers and their families; and better office equipment and office accommodations.

It doesn't do much good to pay the younger men more and forget the older men. The smart young men can see that long-time employment under such conditions—career work—will bring them little. In addition, it is a matter of fairness to maintain an equitable salary scale in all levels. Personal considerations, as helpful interest in domestic and housing problems, are essential personnel factors and, as such, cannot be overlooked. Also, many of our public engineering offices are not such as to make employees proud of their working surroundings.

These factors are largely the responsibility of the chief engineer of the organization, whether this is city, county or state, but are also matters of vital interest to the engineering profession. The other item mentioned above—contact with engineering colleges—is of great long-range importance. How it can best be worked out, we do not know, but it also is essential in any program looking toward better engineering and better conditions for engineers.

Are Engineers Scientists and Administrators?

We have before us a memorandum from the American Public Health Association regarding the Lasker awards to be conferred in 1949 "for scientific research and for administrative achievement." Accompanying this memorandum is a list of the 23 awards made during the past three years. We have scanned this list hopefully, but we see no sign of any engineer on it. Can it be that engineers are not scientists and that they lack administrative ability? It was your editor's impression, based on an extended acquaintance, that there are numerous outstanding engineers who are members of the APHA and who could qualify under both headings. We hope the time will come when this fact is recognized more widely.

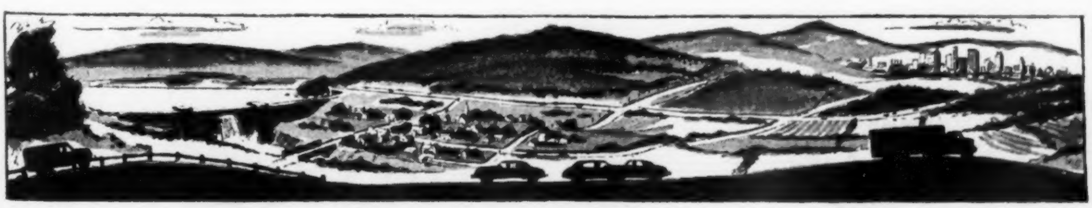
Draft Provisions and Active Duty for Reservists

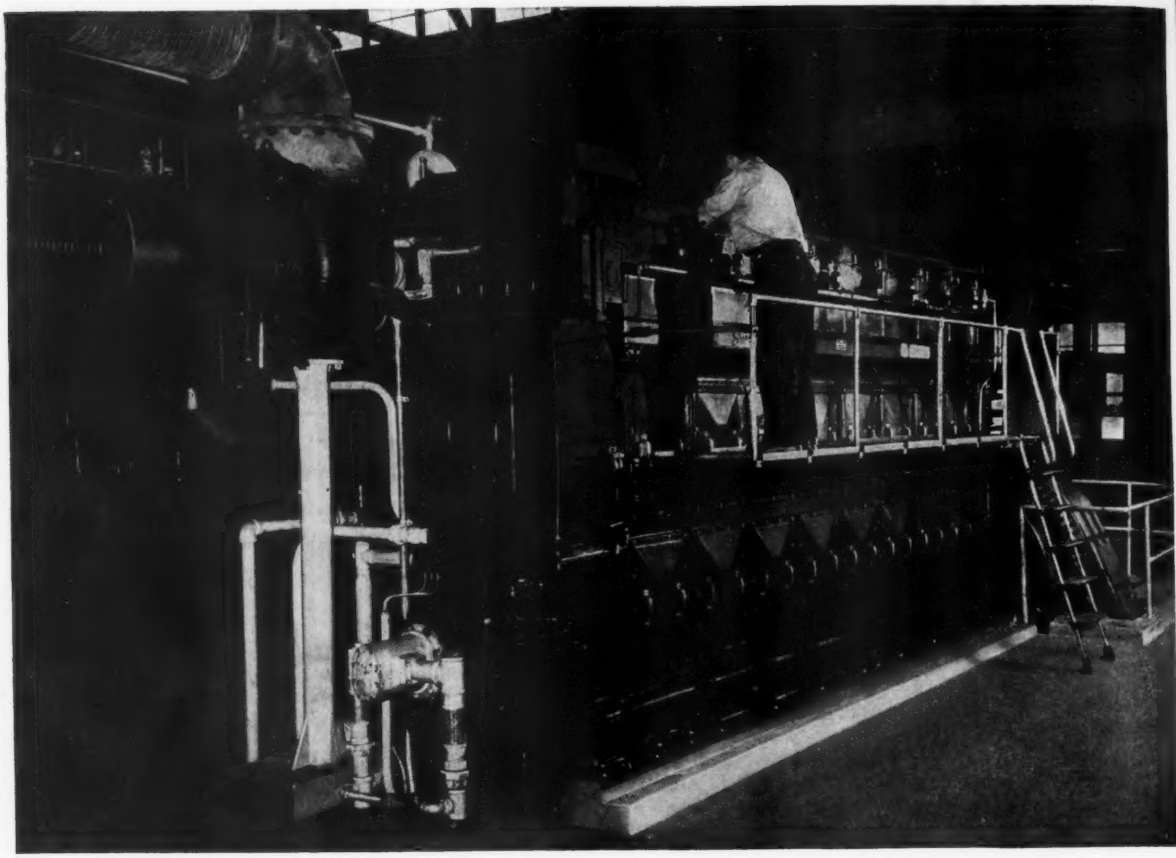
Under existing laws, draftees, have essentially the same right for reinstatement in the jobs they left when drafted as they had during the war. Main provisions are: The individual must have left a job other than temporary; he must have received an honorable discharge; and he must apply for reinstatement within 90 days after discharge. In addition, if disabled to the extent that he cannot perform the duties of his old job, he must be given one of like seniority status and pay, or the nearest approximation thereto that is possible.

The time limitation for employment rights is 3 years; if the enlistment or service period is voluntarily extended beyond 3 years, reemployment rights are lost. Reserve officers (and enlisted reservists) are covered by the reemployment provisions regardless of whether they go on active duty with or without their own consent, up to the 3-year period.

It is probable that the reemployment provisions do not apply to reserve personnel for short periods of training, as for normal 2-week summer training periods. This appears to be a defect in the law which should be corrected, since the selective service act requires that a man, after he has served his induction period, must maintain his status in the reserves for a period of years. This will be of mounting importance, because the number of people in the reserve will increase materially and may reach the point where summer training will require extensive cooperation on the part of employers and of the armed forces in scheduling training periods.

The statements above do not take account of the problems of deferment of scientific personnel, including students in engineering schools. Our stand on that is very simple: We do not think that Selective Service is qualified to handle this matter. It should be referred to the National Security Resources Board or other agency with adequate facilities for determining national needs for professional personnel.





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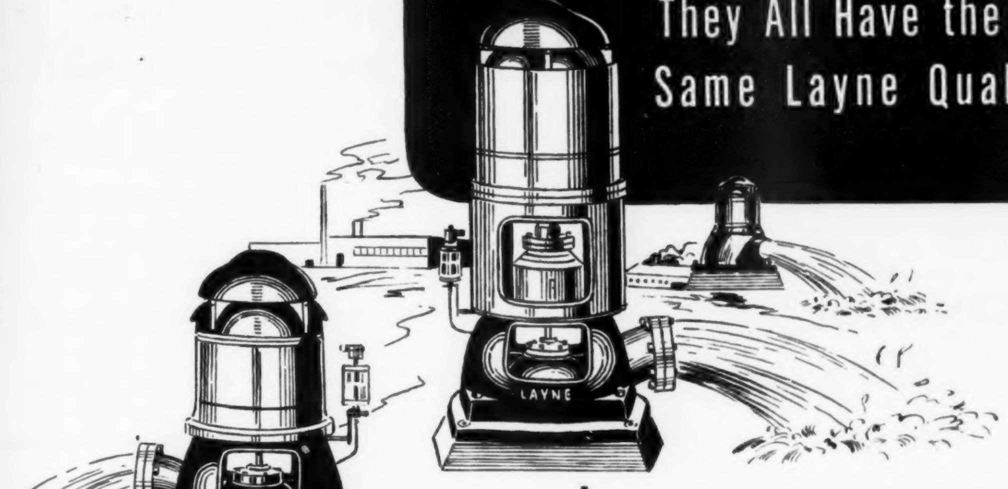

Layne has constantly maintained the highest quality of materials and finest precision manufacturing in all of their Well Water System installations. The smallest are just as substantial in construction and as high in efficiency of operation and always produce proportionately as much water as the biggest. This fact has been proven time and again to the complete satisfaction of hundreds of owners.

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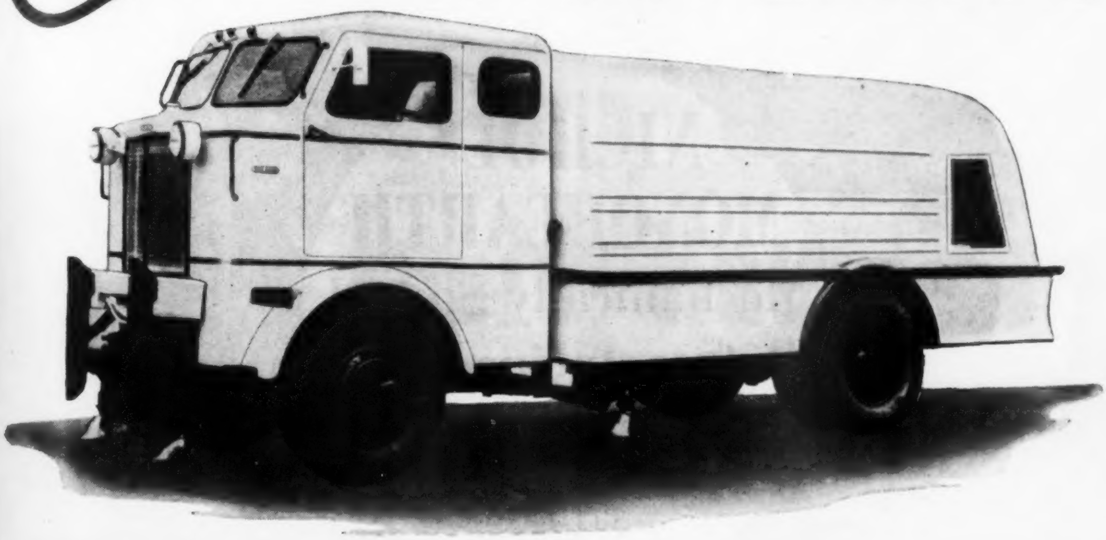


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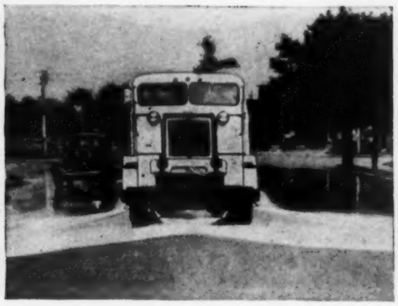
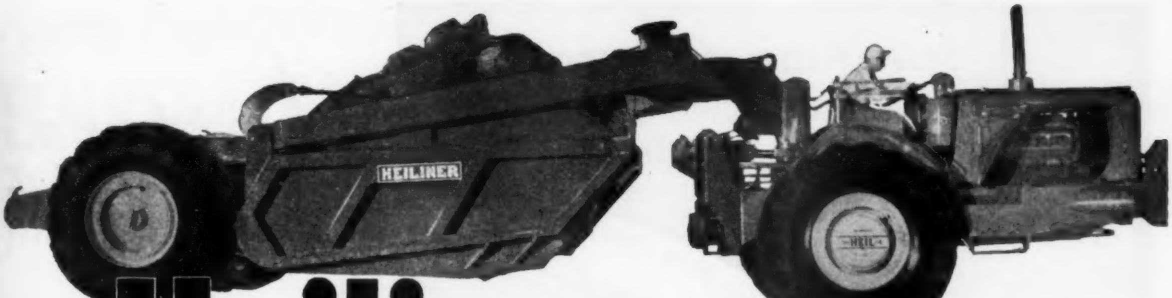
HELP KEEP





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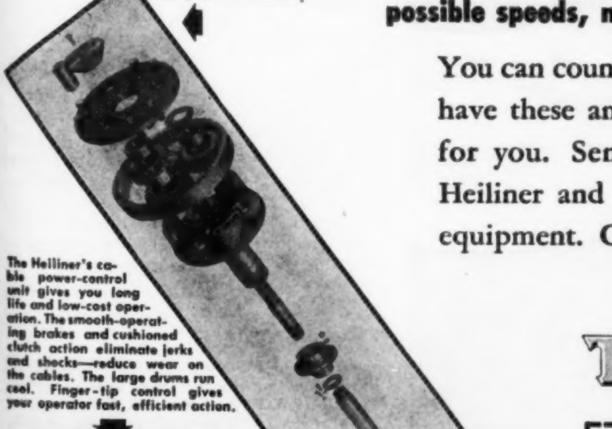
You can count on larger earthmoving profits, when you have these and many other Heiliner features working for you. Send for complete information about the Heiliner and the complete line of Heil earthmoving equipment. Check the coupon and mail it today.



The Heiliner's cable power-control unit gives you long life and low-cost operation. The smooth-operating brakes and cushioned clutch action eliminate jerks and shocks—reduce wear on the cables. The large drums run cool. Finger-tip control gives your operator fast, efficient action.

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Letters

THE "HOBO" FUND

Receipt is acknowledged of your letter of March 22 enclosing a check for the article "High Costs Seriously Retard Highway Building Program" which appeared in your March issue. Our engineers do not accept personal reimbursement for an article of this nature. After considerable thought we have decided you might appreciate having your check put to good use and we have therefore placed it in our "HOBO FUND" (Highway Office Benevolent Organization). This fund takes care of weddings, sickness, funerals and other calamities.

You therefore have the thanks of all our employees from the mimeograph room in the basement through the stenographers, typists and engineers, clear to the front office.

Richard H. Wilson,
Ass't State Hwy. Engr.,
California Division of Highways

(Ed. Note: We hope to be able to contribute still more in the future to the HOBO FUND, but the girls in this office want to know how come weddings are included in that word "calamities.")

WE HOPE SO

In going over my volumes of PUBLIC WORKS, I came across a splendid article on retaining wall design, and another on small dams. Do you have other such articles of interest to my design department? I have saved many other helpful articles, such as design on small sewage works. The boys in the office appreciate your publication.

ASHLEY Q. ROBINSON,
City Engineer,
Newton Centre, Mass.

(Ed. Note: These were among the numerous "complete" articles that have been published in PUBLIC WORKS in late years. We try to have two or three of these each year. Recent such articles had to do with the design of sewers, design of small sewage treatment plants, low cost road construction, and operation of water treatment plants. Within the next few months, we will have one on storm sewer design.)

BOOK REVIEWS

ENGINEERING THE NEW AGE

This is a book that is difficult for the literal-minded engineer to evaluate, but most of us will find it interesting. For

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instance, there was the way Hercules handled his sanitary engineering job of cleaning the stables, which job, it will be recalled, contained a "time-is-the-essence" clause. The engineering projects of the Egyptians are covered briefly and interestingly. And so on, up to modern times, we find an interesting running account of much engineering. "Creating the Cities Anew" and "Learning How" are the concluding chapters. By John J. O'Neill. 314 pp. $3.50. Ives Washburn, Inc., 29 West 57th St., New York 19, N. Y.

SUBSURFACE SEWAGE DISPOSAL

This publication is Bulletin No. 23, issued by the Engineering Experiment Station of the University of Florida. The text was prepared by John E. Kiker, Jr., Associate Professor of Public Health Engineering, formerly district engineer of the New York State Department of Health and Major in the Sanitary Corps. While the text is devoted primarily to Florida conditions, the data in it are applicable anywhere. Prof. Kiker has developed the information on soil percolation so that it can be applied more easily and accurately, and he has given clear and usable methods of procedure in design. While much of the text is devoted to subsurface disposal problems, the design of the house sewer and the location and design of the septic tank are also considered. We think this is one of the best texts yet available on this subject. We believe that it can be obtained by writing to the author at the University of Florida, Gainesville, Fla.

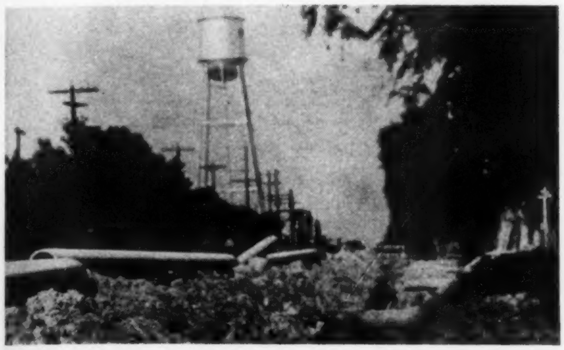
DESIGN OF STEEL BUILDINGS

This is the 3rd edition of this book by Harold D. Hauf and Henry A. Pfisterer. Material in previous editions on welding has been expanded to an entire chapter. Chapter X is a step-by-step procedure in the design of the structural framework for a small business building and includes the development of a set of working drawings. Chapter headings include: Riveted Connections; Plate Girders; Columns and Struts, Roof Trusses; and Wind Stresses. 280 pp., 139 figures. $5. John Wiley & Sons, Inc., 440 Fourth Ave., N. Y.

LIME IN TREATMENT PROCESSES

This is a compilation of data on the principal methods of lime feeding and types of feeders, slakers, hoppers, solution pots, etc., presenting the advantages and disadvantages of each. Information is also given on the most efficient methods of feeding lime in dry or slurry form. Considerable information is included on the chemistry of lime. The author is Dr. Willem Rudolfs and the booklet of 71 pages is published by National Lime Ass'n, Washington 5, D. C. One copy free on request; additional copies 50¢.

This intrinsic resistance to corrosion has been substantiated by numerous Transite installations. Some of these have been exposed to highly aggressive soils, both alkaline and acid, for many years. Many are now serving as replacements under conditions so destructive that the useful life of the pipe materials previously used had been seriously curtailed.



Transite Pipe was installed in this Texas city ten years ago to replace another pipe material that had been destroyed by soil corrosion in 7 years. The Transite mains are still on the job today with a long useful life ahead of them.

In one such installation, a Transite main installed during 1932 in an extremely corrosive soil was recently made the subject of careful study to determine its condition. Sections of the pipe, including couplings, were dug up and shipped to the factory for test. There was no evidence of deterioration. Pipe and couplings readily withstood the original factory pressure test, equivalent to four times the normal working pressure of the line.

Like thousands of other communities, this West Virginia city selected Transite Pipe because it promised assurance of maximum life. Today, after 14 years of service, the first installation of Transite has already fulfilled this promise by outlasting the pipe material previously used.

Certain types of industrial service provide an even more severe "proving ground" for the life expectancy of pipe materials, and here, too, Transite Pipe has demonstrated exceptional corrosion resistance. Coal mine service is a typical example. Here acid mine waters are frequently so corrosive that they have destroyed ordinary pipe materials in a matter of a few months or years. Yet Transite Pipe has handled these same waters under working pressure up to 150 lbs. for periods from 10 to 15 years with little, if any, indication of deterioration.

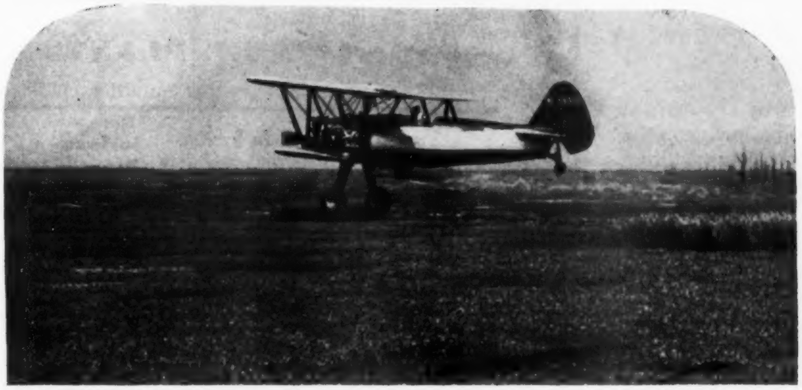
Corrosive soil conditions were so severe at this location in a prominent New England city that the life of the pipe material formerly used was only 15 years. Transite Pipe, put in as a replacement in 1934, continues to give the same efficient, dependable service as the day it was installed.

To evaluate the ability of pipe materials to withstand soil corrosion, the National Bureau of Standards has conducted an extensive series of field tests. These studies are based on examination of hundreds of pipe samples periodically removed from severely corrosive soils. In these and similar tests, Transite Pipe has consistently demonstrated its superior resistance to soil corrosion, confirming the long life expectancy which this asbestos-cement pipe has evidenced in thousands of water works installations.

Transite's ability to provide long-term, dependable service is well illustrated by its performance in coal mines, where it consistently outlasts other pipe materials in carrying corrosive mine drainage waters. The 36" Transite line shown above has been conveying acid mine waters for 15 years.

PUBLIC WORKS
★ MAGAZINE ★

MAY • • 1949
VOL. 80 NO. 5



AERIAL SPRAYING
Controls Reservoir Growths

AQUATIC growths, in the fall of 1947, covered approximately 700 acres of the 2,400-acre Sheldon Reservoir, Houston, Texas, and were very numerous in the 12.3-mile earthen canal connecting the reservoir and the Channel Pumping Plant on Clinton Drive. These growths had accumulated over a considerable length of time and had reduced the effective flow capacity in the canal from 40 mgd to 25 mgd. The Sanitary Engineer of the Water Division, Clyde R. Harvill, undertook the control and elimination of these growths.

The following information on methods and results are as reported by Mr. Harvill.

Methods and Cost of Treatment

As a first step, the growths were identified by Dr. Edgar C. Tullis of the Bureau of Plant Industry, Department of Agriculture, Beaumont.

A number of weed killers and various methods of weed killing were investigated, and all available authorities on the subject of plant eradication were consulted before remedial measures were undertaken. It was decided that the chemical 2,4-dichlorophenoxyacetic acid, or 2,4-D, offered the most efficient means of eliminating the growths. Therefore, in the latter part of September, 1947, the reservoir was sprayed by plane with the triethanolamine salt of 2,4-D in aqueous solution. The dosage used was 1 lb. of the acid per acre, or 1 quart of the triethanolamine salt (which is 40% 2,4-D acid and weighs 10 lbs./gallon) in sufficient water to cover an acre. For plane spraying 15 gallons of liquid were used per acre, and for hand spraying 200 gallons of liquid per acre.

See list of plants on page 24

The results of the plane spraying were most gratifying in that approximately 80% effective kill of the surface and emergent plants was observed in less than a month. The cost of this work, including plane service was $2.99 per acre. The canal was hand sprayed with about 50% effective kill. Later it was sprayed by plane with results similar to those obtained in the reservoir. In contacting other users of chemical weed killers, we found that they also obtained better results by using planes than by hand-method application.

Conditions in 1948

In the spring of 1948, new growths were observed in the north end of the reservoir in an area which had received no 2,4-D treatment in 1947. The predominant growths encountered were Water Lily, Water Shield, Water Primrose, and Cattail.

This area was sprayed by plane with an aqueous solution of 2,4-D, applied at the same rate of 1 lb. of acid per acre, at a cost of $3.50 per acre. The increase in cost over the 1947 figure was occasioned by the increased distance of the landing field from the reservoir, and consequent increased cost of plane service. Final evaluation of the results from this application of 2,4-D was practically impossible due to reductions in the water level in the reservoir; however, observations indicate that 2,4-D is an effective killer of Water Primrose, Water Shield, and Water Lily.

Submerged Plant Treatment

In June, 1948, with the low water level in the reservoir, numerous areas of Pondweed, ordinarily a submerged plant, were observed growing on the surface of the water. This condition afforded our first opportunity to treat this type of growth with 2,4-D, and on June 21st, 350 gallons of 2,4-D in diesel oil were plane sprayed on the Pondweed areas. This treatment appears to have halted the further spread of these plants but additional treatments will be required to kill this plant, which has an almost impenetrable waxy leaf surface.

Results indicate that Arrowhead, Sedge, Pond Lily, Water Lily, Water Shield, and Water Plantain are killed by 2,4-D. Cattail is more resistant to 2,4-D than any plants yet encountered. In June, about 15 experimental areas of Cattail were hand sprayed with various weed killers and combinations of weed killers to determine the most efficient method of controlling them. To date, Dow Contact Herbicide, followed by an ester preparation of 2,4-D on the young regrowth, shows the most promise of killing Cattail.

Summary of Results

In summary, our results with 2,4-D indicate that it is a satisfactory agent for the control of aquatic growths. Excellent effects over a large area of water were obtained at a reasonable cost. As was to be expected, some plants are more resistant to 2,4-D than other plants; some plants require the use of a "carrying agent," such as oil, to provide adequate time for 2,4-D to react; some plants can be killed with 2,4-D at one season of the year but are resistant at other seasons of the year; in general, the younger the growth, the more easily it is killed. It is anticipated that our future control measures will be largely concerned with treating the growths which have not been killed by the triethanolamine salt of 2,4-D to date.

The field of chemical weed killers is relatively new and a number of products show promise of killing plants which are 2,4-D resistant. We are, through the cooperation of Dr. Tullis and the Dow Chemical Company, presently investigating several new herbicides, and the results thus far indicate that complete control of aquatic growths by chemical methods is entirely possible.

LIST OF PLANTS

The following plants were present in greatest abundance:

Emergent Plants	Cattail Pond Lily or Egyptian Lotus Water Plantain Arrowhead Sedge	**Surface Plants**	Water Lily Water Shield
		Submerged Plants	Pondweed Stonewort

No Effect on Fish Life

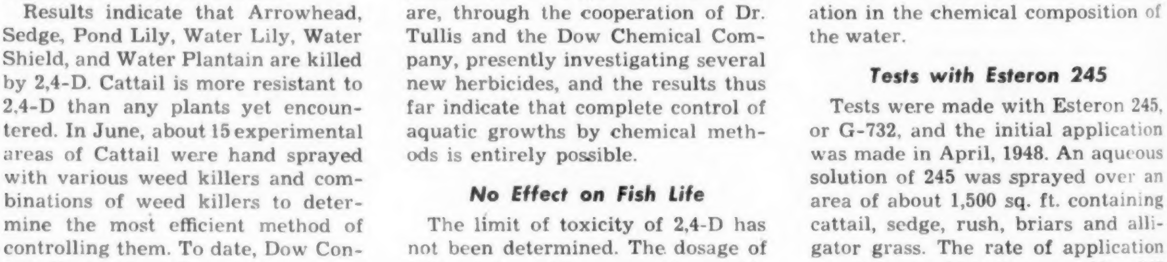
The limit of toxicity of 2,4-D has not been determined. The dosage of 1 lb. of the acid per acre is considered the optimum dosage and no toxic effects to fish or livestock have been observed. Sheldon Reservoir is a popular fishing area, and close observations of the possible toxic effect of 2,4-D to fish have been maintained following all applications of the herbicide. On the one occasion when diesel oil was used as a carrying agent, no adverse effect to fish was demonstrated. However, it should be noted, that the oil compound was applied only to the areas of Pondweed, not to the open water surface, and the final dilution of oil and water was so great that no oil slicks could be observed 4 hours after the application.

The water to which 2,4-D has been applied is a raw water supply developed for irrigation and industrial purposes, and does not serve as a drinking water supply. It was thought that the applications of 2,4-D might alter the chemical or physical characteristics of the water, but analyses run at regular intervals following each treatment with 2,4-D, showed no appreciable increase in the color or turbidity and no alteration in the chemical composition of the water.

Tests with Esteron 245

Tests were made with Esteron 245, or G-732, and the initial application was made in April, 1948. An aqueous solution of 245 was sprayed over an area of about 1,500 sq. ft. containing cattail, sedge, rush, briars and alligator grass. The rate of application was 1 lb. of acid to the acre. Also, 245 with diesel oil as the carrying agent was applied to areas of water shield, water lily and cattail.

The results obtained from 245 compared favorably with those obtained with 2,4-D. Both products appear to be satisfactory agents for the elimination of the majority of aquatic growths, but 245 appears to give superior results on briars. Neither agent, in the concentrations used, has been effective in preventing the regrowth of cattail.



HOW TO BUILD

● *CONSTRUCTION METHODS for this type of surface treatment are described in this article. Note wide shoulders and good alignment.*

BETTER BITUMINOUS PAVEMENTS

Through better design plus sound standards of construction and maintenance.

T. V. FAHNESTOCK
Bituminous Engineer, North Carolina State Highway and Public Works Commission

IN THE design of bituminous pavements each year finds added emphasis placed on the subgrade and base course. This is proper, for the service value of the pavement depends to a far greater degree on the foundation upon which it is placed than the actual design of the pavement itself.

A fact that is frequently overlooked is that the design of the pavement for rural roads begins with the location and drainage survey. A soil survey of the area in which the road is to be located, if made by an experienced soils engineer, will not only be of assistance in locating the road, but will pay dividends all the way through.

The Necessity for Adequate Drainage

Adequate drainage is a must in all road construction and the drainage should be provided ahead of the grading. This is stipulated in all specifications, but often it does not receive the proper attention and soft places develop in the grade which either delay the placing of the pavement or result in subsequent failures.

In laying the grade line for bituminous pavements, flat grades in cut sections should be avoided where possible; and a break from a steep to a flat grade is especially undesirable. Where such grades are necessary, the roadway ditches can be constructed to a grade, varying from the grade of the center line, and be provided with sufficient fall to be self cleaning. Even the best maintenance crews are not able to keep a road properly drained at all times without the help of the designing engineer.

Soil Examinations to Help in Pavement Design

During grading operations, underground sources of water are sometimes encountered which have not been detected when the drainage survey was made. In each case, the condition found should be studied in order that an adequate system of underdrains may be installed.

Best results are obtained if the grading and drainage work is performed some time in advance of the placing of the base course and pavement. In any event the proper compaction of embankments is necessary, and special attention is required to obtain this at grade points, near structures, and over pipe culverts.

When the grading and drainage have been completed, soil samples can be taken from the subgrade and tests made on these will be of help in determining the thickness of base and pavement to be used. If the pavement is designed before the road is graded, the designing engineer must rely on the data obtained from the original soil survey. The importance of the more complete data is obvious.

Unfortunately, there is no proved mathematical method of designing flexible pavements; therefore, designing engineers rely largely upon experience and judgment along with such other factors as soil tests on the subgrade material, the expected volume and weight of traffic, climatic conditions and service records of similar roads. In this connection the reader's attention is called to a bulletin printed early this year by the Highway Research Board called "Thickness of Flexible Pavements For Highway Loads." This is one of the series of bulletins on current road problems. Actually it is a revision of Bulletin 8, "Wartime Road Problems." This publication presents a method of estimating the thickness of flexible pavements necessary for highway loads, and also reviews other important procedures of design.

● *WIDENING a 16-ft. pavement preliminary to resurfacing with a hot-mix sand asphalt, using a mechanical finishing machine.*

Bases and Sub-bases for Bituminous Pavements

The types of bases now generally used under bituminous pavements include selected soil, soil cement, soil bituminous, gravel, stone, or a combination of these. The type used should be determined only after a thorough survey has been made of available local materials and consideration given to the factors enumerated above.

Another question which arises in connection with sub-base or base design is the width to which they should be placed. In some sections of the country and under certain climatic conditions, it may be desirable or even necessary for the base to extend through the shoulders. In the southeast this is not deemed necessary and the bases are constructed as a trench section to the same width as, or one foot wider than, the pavement. If desired, drains may be installed through impervious shoulders on the inside of curves and at the bottoms of vertical curves. In the opinion of the writer these are not necessary, the preferred procedure being to open a series of narrow trenches through the shoulders at any points where the base or subgrade becomes unstable due to excess moisture. These trenches permit the wet area to dry and after the pavement has been placed, they are filled with impervious material. The objection to the pervious drains is that clogged ditches or melting snow can force water back under the pavement.

The data following show specifications including gradation, liquid limit, and plasticity index of sub-base material and two types of base material.

● *MECHANICAL FINISHING machine placing a hot-mix sand asphalt surfacing on an old pavement previously widened and leveled.*

Sub-base Course Material Specifications

Materials for this work shall consist of Type A, B, or C materials as defined herein:

Type A material shall not contain more than 40% of aggregate passing the 1-inch and retained on the No. 10 sieve, and its soil mortar (material passing the No. 10 sieve) shall conform to the following weight grading requirements:

Sieve	% Passing
No. 10	100
No. 40	40-70
No. 200	5-35

The fraction passing the No. 200 sieve shall be less than ⅔ of the fraction passing the No. 40 sieve. The material passing the No. 40 sieve shall have a plasticity index not greater than 15 and a liquid limit not greater than 40, when tested in accordance with AASHO T-89, T-90 and T-91. A tolerance of 10% of aggregate retained on the 1-inch sieve will be permitted provided the maximum size does not exceed 1½ inches.

Type B material shall contain more than 40% of aggregate retained on the No. 10 sieve and shall conform to the following requirements by weight:

Sieve	% Passing
1-inch	100
No. 10	30-60
No. 40	20-45
No. 200	8-25

The fraction passing the No. 200 sieve shall be less than ⅔ of the fraction passing the No. 40 sieve. The material passing the No. 40 sieve shall have a plasticity index not greater than 15 and a liquid limit not greater than 40, when tested in accordance with the methods of the AASHO T-89, T-90 and T-91. A tolerance of 10% of aggregate retained on the 1-inch sieve will be permitted provided the maximum size does not exceed 1½ inches.

Type C material shall meet the following requirements:

Sieve	% Passing
No. 10	100
No. 40	40-100
No. 200	5-35

The material passing the No. 40 sieve shall have a plasticity index not greater than 6 and a liquid limit not greater than 25, when tested in accordance with AASHO

T-89, T-90 and T-91. A tolerance of 10% of aggregate retained on the 1-inch sieve will be permitted, provided the maximum size does not exceed 1½ inches.

Soil Type Base Course

Soil type base course shall be classified as Fine Aggregate Type, Case I, or Coarse Aggregate Type, Case II. The use of either type will be permitted unless otherwise specified. Each type shall be as hereinafter provided and shall comply with physical requirements as designated below. The base course material shall be free from vegetable matter and lumps or balls of clay, and shall meet the requirements for one of the gradings given below, using AASHO Methods T-11 and T-27.

Case I. The Fine Aggregate Type shall not contain more than 40% of aggregate passing the 1-inch and retained on the No. 10 sieve, and its soil mortar (material passing the No. 10 sieve) shall conform to the following grading requirements:

Sieve	*% Passing*
No. 10	100
No. 40	40-70
No. 200	5-35

The fraction passing the No. 200 sieve shall be less than ⅔ the fraction passing the No. 40 sieve. The material passing the No. 40 sieve shall have a plasticity index not greater than 6 and a liquid limit not greater than 25, when tested in accordance with AASHO Methods T-89, T-90 and T-91. A tolerance of 10% of aggregate retained on the 1-inch sieve will be permitted provided the maximum size does not exceed 1½ inches.

Case II. The Coarse Aggregate Type shall contain at least 40% of aggregate retained on the No. 10 sieve and shall conform to the following grading requirements:

Sieve	*% Passing*
1-inch	100
No. 10	30-60
No. 40	20-45
No. 200	8-25

The fraction passing the No. 200 sieve shall be less than ⅔ the fraction passing the No. 40 sieve. That passing the No. 40 sieve shall have a plasticity index not greater than 6 and a liquid limit not greater than 25, when tested in accordance with Methods of the AASHO T-89, T-90 and T-91. A tolerance of 10% of aggregate retained on the 1-inch sieve will be permitted provided the maximum size does not exceed 1½ inches.

Traffic-Bound Macadam Base Course

Sieve	*% Weight Passing* Grading A	Grading B
2-inch		100
1½ inch	100	90-100
1-inch	90-100	55-90
½ inch	55-90	45-75
No. 4	35-60	30-60
No. 40	10-35	10-35
No. 200	5-20	5-20

Grading A material may be used for the entire thickness of the base course unless otherwise stipulated. Grading B material may be used for constructing the base course with the exception of the top 3 inches which shall always consist of Grading A material.

The material retained on the No. 4 sieve shall consist of clean, tough, durable pieces of aggregate which, when tested in accordance with AASHO. Method T-96, will show a loss not greater than 60%. Shales or shaly aggregate not approved by the Laboratory shall not be used.

The material passing the No. 4 sieve shall be known as "binder" and shall consist of screenings, sand and clay or other material of satisfactory binding value. The material passing the No. 40 sieve shall have a plasticity index not greater than 6 and a liquid limit not greater than 25, when tested in accordance with AASHO Methods T-89, T-90 and T-91.

Construction Procedures for Bituminous Pavements

The sub-base material is used directly under some types of pavement or in conjunction with the macadam bases. The compacted thicknesses of bases used are as follows:

Sub-Base	**3 to 6 inches**
Soil Type	**4 to 12 inches**
Macadam	**4 to 10 inches**
Soil Cement	**5 to 6 inches**
Soil Bituminous	**3 to 6 inches**

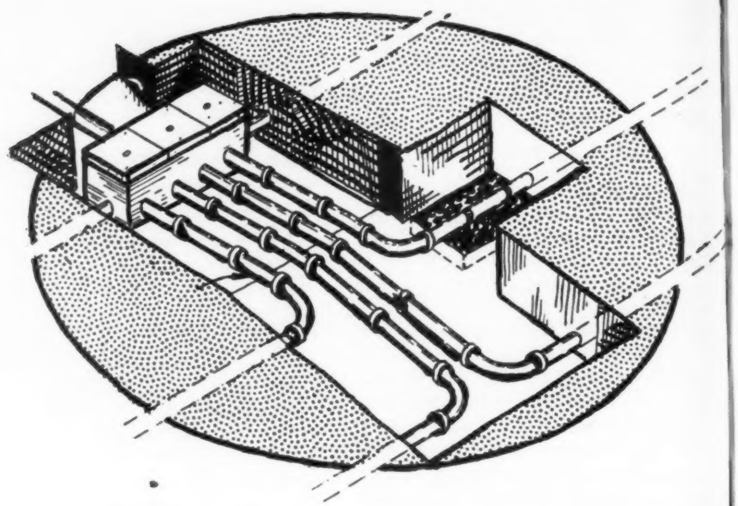
For bituminous surface courses, the simplest and least expensive is the Single Surface Treatment. This consists of a prime of medium-curing cut back asphalt or light tar at a rate of from 0.3 to 0.4 gallon per square yard. After the prime has cured, rapid-curing cut back asphalt, RC-2 or 3, is applied at a rate of 0.2 to 0.25 gallon per square yard and is covered with 10 to 12 pounds of coarse sand or stone screenings. The treatment may be used by traffic at once, but the sand should be kept uniformly spread by dragging with a light broom drag for about two days. This thin surfacing gives surprisingly good results where used by relatively light pneumatic tired traffic, but is not recommended for use on soil cement bases.

In the Double Bituminous Surfacing, the same prime is used followed by 0.4 gallon of 150 to 200 penetration asphalt and 42 to 45 pounds of 1¼ to ½-inch aggregate per square yard. The aggregate is rolled and opened to traffic for ten days or more and then sealed. The seal consists of 25 to 30 pounds of

(Continued on page 81)

● ***WIDENING and surfacing completed, the road is open to traffic.***

HOW to DESIGN



for Subsurface Sewage

This article is condensed from Bulletin No. 23, Florida Engineering Experiment Station, University of Florida, which was prepared by John E. Kiker, Jr., Associate Professor of Public Health Engineering. Though written particularly for Florida conditions, it is applicable to all areas and provides an unusually excellent approach to a difficult subject, present in every community.

WHEN homes are built beyond the sewer lines, individual disposal of sewage becomes necessary. Properly constructed and operated, these individual disposal plants give excellent service. However, relatively little precise information has been available on engineering procedures in the design of the subsurface disposal system, and this is the most important single element in the whole installation. Consideration must be given to the volume of flow of sewage, area available, soil conditions, ground water and the demands of public health.

It is important that every effort be made to determine the volume of water use and sewage flow. Where reliable data cannot be obtained, as when an entirely new project is under way, the sewage flow will have to be estimated. Experience has shown that the following are generally safe bases for estimating the flow of sewage in gallons per person per day: Small houses, 50 gals.; rooming houses, 40 gals., based on potential maximum capacity, boarding houses, 50 gals. on the same basis; hotels with connecting baths, 50 gals., and with a bath in every room, 100 gals., based on capacity; restaurants, 7 to 10 gals. of toilet and kitchen wastes based on maximum daily clientele, with kitchen wastes at 2½ to 3 gals. per meal served; tourist camps or trailer parks, with central bathhouses, 35 gals., and with individual bath units 50 gals.

Day schools, 8 to 20 gals., depending on the presence of cafeterias, gymnasiums and showers; day workers at schools and offices, 15 gals.; hospitals, 150 to 250 gals. and up, based on patient capacity plus staff; factories, 15 to 35 gals. per person per shift, not including any industrial wastes; picnic parks, 10 gals. per patron; swimming pools, 10 gals. per person swimming daily; country clubs, 100 gals. per resident and 25 to 50 gals. per member present on maximum day.

The National Park Service estimates that various fixtures discharge sewage hourly, during the hours when the parks are open, at the following rates: Flush toilets, 36 gals.; urinals, 10 gals.; showers, 150 gals.; and faucets, 10 gals. It is believed that these rates may be applied, without serious error, to fair grounds, ball parks and similar places where the number of such facilities are adequate.

It is important to remember that a subsurface disposal system has a very limited overload capacity, and that design should be based on the maximum probable load.

There is no recognized standard of size universally required by states and cities for septic tanks (or other similar type of tank). The U. S. Public Health Survey has recently completed a survey of practices in this field and has issued a preliminary report which is not yet ready for distribution. It is best to determine the regulations of the appropriate state board of health, or of the city or county in which the installation is to be made. To determine the size of the tank, accurate information on the volume of flow is necessary.

There is generally also a lack of uniformity in the requirements for the size and slope of the sewer leading from the house to the tank and thence to the disposal field. These lines should never be less than 4 ins. in size, and preferably should be larger. In this case, also city, county or state regulations should be ascertained.

The Sewer Line and Settling Tank

Both the tank and the sewer line should be located with judgment. The tank should always be placed as far away from the well or spring as is possible—never less than 50 ft. —and downhill from it. The sewer line to or from the tanks should likewise be kept away from the source of water supply. If cast iron or other pressure type pipe with tight joints is used for the sewer, a greater degree of safety is attained. Such material should always be used if the line must pass within 50

● *DETAILS of distribution box for disposal systems on side hills. The laterals are laid out to conform with the contour of the surface and flow to each lateral is controlled by the distribution box. This method permits maintaining a uniform slope of 0.25% in the laterals.*

Disposal

ft. of a well or spring or a pipe under suction or negative pressure.

Designing the Disposal System

The first step in designing a subsurface disposal field is to determine its location. A distance of 100 ft. from any well or other source of water supply is most desirable, and the disposal system should be downhill from the water source. Also, the disposal area should be at least 10 ft. from property lines or dwellings and 25 ft. from any stream or ditch. Unshaded ground, away from trees, is preferable. Soil conditions are highly important. Hardpan, impervious clay, rock or high ground water may prevent satisfactory service, and installation under such conditions is generally a waste of money.

The percolation test is the best measure of the ability of a subsurface disposal field to operate satisfactorily. This is a test of the absorptive ability of the soil. It is performed as follows:

1. Dig holes about 1 ft. square to the depth at which is is proposed to lay the drainage field and at representative points.

2. Fill the holes with water. When the ground has become thoroughly soaked and the water level is within 6 or 8 inches of the bottom of the hole, measure the rate at which the water level drops.

3. The time required for the water to drop 1 inch after uniform conditions have been established, as in 2 above, is the **percolation time t.**

The **percolation coefficient of the soil, C** which is the area in sq. ft. required to absorb 1 gal. daily, is determined by the formula:

$$C = (t + 6.24) \div 29$$

For example, assume that it requires 15 minutes for the water to drop 1 inch. Then $t = 15$, and $C = (15 + 6.24) \div 29$, or 0.73, and there will be required 0.73 sq. ft. of bottom disposal trench area for each gallon of sewage per day. With a flow of 1,000 gallons of sewage per day, a bottom trench area of 730 sq. feet must be provided. Based on this design, and using a septic tank of adequate capacity, the subsurface installation has a service expectancy of 20 years.

The Tile Lines and Trenches

Individual lines of subsurface tile should not exceed about 75 ft. to 100 ft. in length; where the volume of sewage requires a greater length of tile, several laterals will be needed. Uniform application of the sewage to all laterals can best be accomplished by distribution boxes. Therefore, these should be provided on all but the smallest installations.

The tile should be laid in a trench and surrounded by clean gravel, broken stone, or other porous material ranging in size from one-half inch to 2½ ins. Where finer material must be used, coarse material should be provided around the joints to prevent clogging. The porous material should extend from a minimum distance of 4 ins. below the tile to 2 ins. over the tile. The top of the porous material should be covered with building paper or other material to prevent the earth fill above from clogging it. Care is necessary in spacing the tile to insure open joints and to prevent the joints from becoming clogged. Metal spacers, commonly called drain-tile connectors, are excellent for this.

The bottoms of the trenches should be made 18 ins. to 24 ins. wide. It is good practice to use 18-inch wide trenches when the percolation coefficient is less than 0.4; 24-inch trenches when the percolation coefficient is between 0.4 and 1.0; and 30-inch trenches when the percolation coefficient is between 1.0 and 2.0. The minimum distance between walls of adjacent trenches is 3 ft., but 5 ft. is better. The lower end of all laterals and distributors should be plugged. Distributor slopes should not exceed 6 ins. in 100 ft. and lateral slopes should not exceed 3½ ins. in 100 ft.

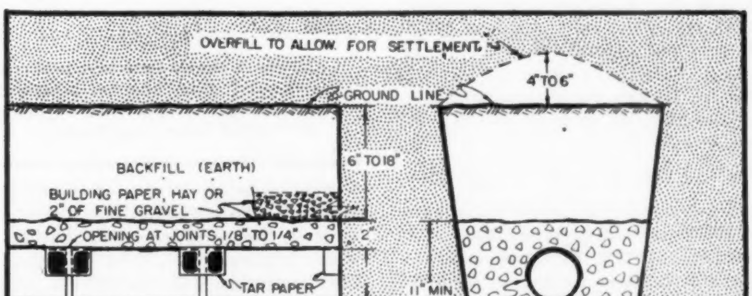
Earth cover for a new absorption trench should be well-tamped and should be overfilled 4 ins. to 8 ins. Unless this is done, the trench may settle below the surface of the adjacent ground, permitting the collection of storm water and the overloading of the trench.

These disposal methods are generally unsatisfactory where the value of the percolation coefficient exceeds 2.0. In fact, where C exceeds 1.5, consideration should be given to the use of other methods.

Dosing Tanks and Siphons

Where the total length of the tile laterals exceeds 500 feet, but is less than 1,000 feet, a dosing tank and single siphon should be used. When the total lateral length is in excess of 1,000 ft., the dosing tank should generally be provided with two siphons. In Florida, installations involving more than 3,000 ft. of tile lateral are not approved. Present

(Continued on page 79)



● ***SECTIONAL VIEWS** of absorption trench and lateral show typical construction features. Most trench bottoms are 18" to 24" wide.*

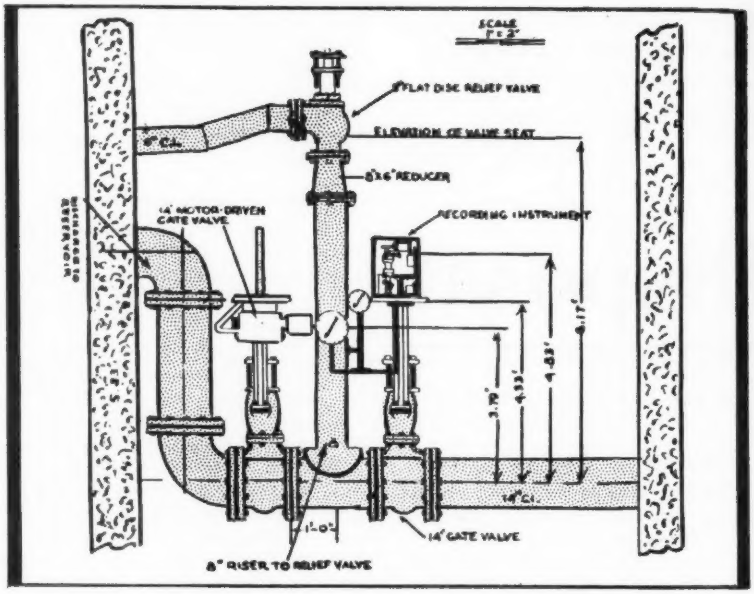
WATER HAMMER

and how to control it!

PHILIP S. DAVY
Davy Engineering Co., LaCrosse, Wisc.

WATER hammer is that rise in pressure above normal which occurs in a water pipe due to the sudden closure of a valve. Such sudden closure stops the flow of water in the pipe. The energy thus liberated is dissipated in distending the pipe and compressing the water, resulting in an increase in water pressure far above normal. The increased pressure may result in pipe and equipment breakage, leaking joints and undesirable noise.

Perhaps the first question is the magnitude of pressure that can occur. This is dependent primarily on the velocity of the water column stopped, but also on the speed of the water hammer, which varies with the diameter of the pipe, its wall thickness, and the material of which it is made. For 6-inch Class B cast iron pipe, the water hammer wave speed is 4,170 feet per second; for 14-inch Transite pipe, Class 150, it is 3,320 feet per second.



● ***WATER HAMMER** caused by too rapid gate closure was reduced by the 5" relief valve. Recorder graphs the changing pressures.*

How to Compute Water Hammer Pressure

The excess pressure **h** that is built up in a 6-inch Class B cast iron pipe, in which the velocity of flow is 5 ft. per second, is found by the formula $\mathbf{h} = \mathbf{a}\ \mathbf{v} \div \mathbf{g}$, where **a** is the speed of travel of the water hammer wave in feet per second; **v** is the piped water velocity destroyed by the closure of the valve; and **g** is the acceleration of gravity or 32.2 ft. per second. Then:

$$\mathbf{h} = 4{,}170 \times 5 \div 32.2, \text{ or } 647 \text{ ft.}$$

which is the equivalent of a pressure of 281 pounds per square inch. The creation of this pressure requires that the valve be closed very quickly, a matter which will be considered in more detail later. The length of pipe line has an important bearing on this pressure as it governs the time **T,** required for the water hammer wave to travel to the end of the line and return. Assume that the length **L** of the line under consideration is 10,000 ft., **T** would be 2 x 10,000 ÷ 4,170, or 4.8 seconds for 6-inch Class B cast iron pipe. If valve closure requires more than 4.8 seconds, the pressure created by the water hammer would be less than the theoretical 281 psi which was determined above.

These data, in practice, are affected by several factors; pipe loops and dead ends tend to complicate the problem. However, application of these formulas will give a basis for estimation of conditions. In most cases, it will be found that only the final portion of the time required to close the valve can be considered as determining the "time of closure." The last 15% to 25% of the normal valve closing time is generally controlling.

TABLE 1—WATER HAMMER RELIEF IN SMALL PIPING

1 Pipe	2 Ft. Length	3 Psi Static	4 Gpm Discharge	5 Fps Velocity	6 Max. Water Hammer	7 Air Provided	8 Resultant Pressure
1" gal.	62	50	40	15	793 psi	59 cu. in.	128
1" gal.	376	50	20	7.5	498 psi	109 cu. in.	143
1½" gal.	209	36	63	10	706 psi	185 cu. in.	131
2" gal.	121	42	154	15	859 psi	331 cu. in.	72
2" gal.	121	42	154	15	859 psi	62 cu. in.	569

Column 3 shows the static pressure in the pipe; column 6 is the maximum measured water hammer pressure; column 7 shows the cubic inches of air at flow pressure provided by the relief; column 8 is the resulting pressures after relief valve installation.

Some Methods of Curing Water Hammer

There are several basic methods of controlling water hammer. These will be discussed separately:

Relief valves of the spring loaded type are especially valuable for pipes larger than 3" or 4" but less than 30" diameter. The size of valve required depends on the velocity of

the water in the pipe and is independent of the length of the water main.

Air chambers are very effective for small pipes—those less than 3" in diameter. The air chamber size required varies as the square of the velocity of the water and also varies directly with the length of the main, since it must store the excess volume of water necessary to reduce the pressure. Maintenance is required to replace the air continually being absorbed by the water. In small pipes, these disadvantages are relatively minor and air chambers are very useful.

Water hammer arrestors may be either mechanical or mechanical pneumatic. In operation, these are governed by essentially the same laws that affect air chambers. For large piping, the cost is greater than for relief valves.

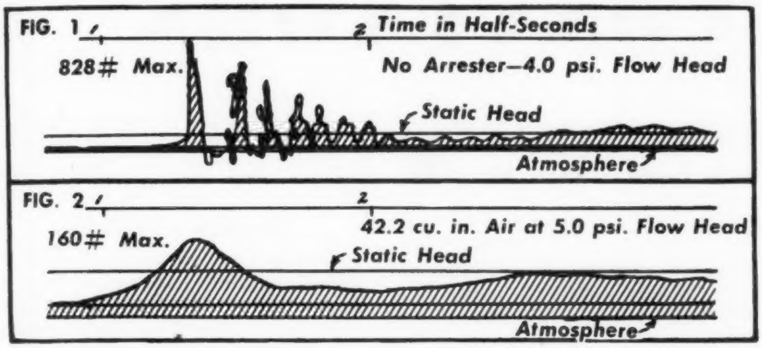
Surge tanks provide a large vertical open water column free to move with pressure fluctuations. Application to medium and high pressure installations is limited by the height and size. For example, a pressure of 50 psi requires a height of 115 ft.

Slow closure of valves is one of the simplest methods of preventing excess pressure due to water hammer. There are two important factors to be remembered. First, the time of closure must be considerably greater than $\mathbf{T = 2\,L \div a}$. Second, the "effective time" of valve closure, usually the time required for the final 15% to 25% of closure—is controlling.

Velocity reduction is a simple method of excess pressure reduction. Thus, a valve on the line may be partially closed, reducing the velocity in the line when the draft on it is heavy. This, though reducing the amount of water available, may not be objectionable.

Many water hammer difficulties occur in small pipes. In general, air chambers and mechanical pneumatic arrestors represent the best solution to the small pipe water hammer problem. Air chambers are the cheapest, but have disadvantages: (1) Make-up air is essential or the air chamber will quickly become water-logged and useless; (2) it is difficult to provide adequate volumes of air where flow pressures in the pipe are considerably below static pressures, as much air is lost in such cases by expansion; (3) the volumes of air required increase rapidly with pipe diameter and length and velocity of flow.

Air absorption can be overcome by using an arrestor which seals air in a bellows. The difficulty of providing sufficient air can be partly overcome by arrestors using air or gas under pressure in the bellows. The difficulties caused by increased size, length and velocity cannot readily be overcome.



● ***DIAGRAMS** of water hammer forces in a 1" pipe show relief given by air chamber. Note that scale is not identical in the two charts.*

Table 1 shows how very high water hammer pressures can be built up under conditions that are not unusual. The data shown are typical for conditions with quick-closing valves, and they also show how reasonable volumes of air relieve pressures appreciably.

As a general rule, the relief device should be located as near the valve causing water hammer as possible.

Check valve hammer is not generally cured by slower valve closures; in fact, these slower closures may intensify such noises and more rapid closure may reduce them. If the check valve closes before the forward motion of the water is stopped, but after velocities have been decreased, "slam" will not occur. If closure occurs too late, forward motion continues and the flow reversal, striking the closed valve flapper, causes the trouble. Tilting disc, spring-loaded weight and cone type valves, properly adjusted, will solve normal problems.

Examples of Field Problems

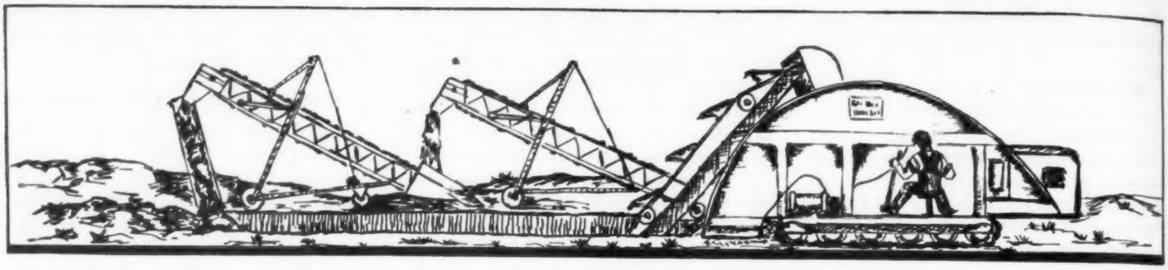
A 34,000-ft. line of 14-inch Transite at the Proviso railroad yards near Chicago, constructed in 1937, drew water from the city of Chicago system. The line terminated in a float-controlled reservoir. Troubles causing pipe leakage were traced to the too rapid closure of the 14" motor driven gate valve at the outlet end of the line. A 5" flat disc relief valve was installed, which reduced pressures satisfactorily, as indicated by a water hammer recorder installed to determine the pressures. The 14" valve closed in 71 seconds, but only the last 11 seconds resulted in a pressure rise. The time required for a complete round trip of the water hammer pressure wave was 20½ seconds, based on a = 3340 fs for 14" Transite pipe and a length of 34,000. Theoretical velocity was 3320 fs. A pressure rise of 155 psi developed before the relief valve was installed. This was reduced to 32.5 psi. Research work was done on this project by the writer, under the direction of L. H. Kessler, then professor of Hydraulic and Sanitary Engineering at the University of Wisconsin.

A similar relief valve installation on a railroad water crane at Fremont, Nebr., reduced recorded pressures from 347 psi to 70 psi.

The city of Phillips, Wisc., had difficulty with water hammer when water was drawn directly from the city main to locomotive tenders. The water pressure built up by abrupt valve closures burst water tanks and caused unpleasant noises in homes near the railroad yards. The valve on the main pipe line leading to the railroad yards was throttled and kept in this position. As a result, velocity in the line was so reduced that water hammer was no longer objectionable, though a longer time was required for filling the tenders.

Summary

The theoretical pressures that will be developed can be determined by the formulas already given. The actual pressures may vary considerably from the theoretical pressures and can be determined only by test, since the period of "effective valve closure" may be much shorter than the total time required to close the valve. In general, on larger pipe lines, relief valves are most effective; and on smaller pipes, air chambers and water hammer arrestors give satisfactory results.



FILL-AS-YOU-GO WITH BELT CONVEYORS

Continuous backfilling of trench speeds and simplifies construction of sewer and avoids open trench hazards.

WARREN W. PARKS
Village Manager, Indian Hill, O.

IN order to provide sanitary facilities for a portion of the Village of Indian Hill near Cincinnati, Ohio, an outfall line, out of proportion to the system itself, was required by the unusual topography. Most of this Village, comprising some 10,500 acres of rather rugged terrain, will probably never have the benefit of sanitary sewers. This is true, partly because of the topography, and partly because of the character of its development.

A Zoning Ordinance, adopted a few years after incorporation of the Village, restricts buildings to one-family dwellings, with the usual accessory structures. It also establishes minimum lot sizes in three districts. In about one-half of the Village, no lot may be less than five acres; in one-third of the area, three acres; and in the remaining one-sixth, one acre.

The subject of this article is the sewer which serves about 400 acres of the one-acre district. It is not too difficult to dispose of sanitary wastes from one dwelling on a tract of three or five acres, even if the soil is not too absorptive. But a large number of dwellings located on lots even as large as 100 x 450, can result in an unsanitary situation which can not easily be corrected. In our case, it was necessary to construct the sewer in advance of contemplated expansion, for existing scattered residences were beginning to cause difficulties.

How the Project Was Financed

The financing was provided by a reserve fund on hand in the Village treasury which will be reimbursed by benefit assessments to be paid when and if each possible building site in the area is developed. Immediate payment was required only for existing residences connected at the time of completion of the sewer.

Present and future subdivisions in the area provide their own lateral mains. Where such mains are provided in this way, each property is assessed only a share of the outfall sewer cost. An explanation of the method of dividing the total cost will be given later, including the cost of lateral construction.

The only available existing sewer, with which a connection could be made by gravity, was located 1¼ miles beyond the area to be served. To reach this, the outfall line had to follow an irregular creek bed carved out of limestone and shale. Several crossings under the bed of the stream were necessary, and there were some places where we had to build the sewer directly in the bed of the stream. It is evident that most of this line had to be fully encased in concrete for proper protection. In trenching, much of the material had to be loosened by blasting and then cast out by power shovels. Mud was a constant obstacle to the moving of equipment.

Construction Problems

One section of the outfall was laid alongside a shallow pond. The sewer grade was about two feet below the pond surface. Construction was facilitated by partial de-watering of the pond. Poor soil conditions were encountered, however, which required underdrains and extra gravel fill to support the pipe. For this section, asbestos cement sewer pipe was used with asphalt joints, to prevent infiltration when the pond was refilled.

In the manhole nearest the outlet

VIEW from rear, second conveyor is filling trench.

of the outfall sewer line, a Parshall flume was constructed, which will be used in case it becomes necessary to measure the sewage volume contributed by Indian Hill to the County system.

The laterals built by the Village in existing streets were mostly laid alongside the edges of pavements. Crossovers of 6" vitrified pipe were installed to take care of all possible building sites on the system, as provided for by the Zoning Ordinance. Each crossover was designed to serve two dwellings.

Backfilling With Belt Conveyors

The contractor used an ingenious method for backfilling which avoided most of the open trench hazards along the pavement. The excavating was done by a bucket type machine with a horizontal conveyor belt, operating at right angles to the trench, for handling the excavated material. This dirt was not allowed to fall to the ground, but two independent belt conveyors were attached to the digging machine, parallel to the trench, so that as the dirt came from the trencher it was discharged to the first conveyor belt. This, in turn, discharged to a second conveyor which deposited the dirt back in the trench where the pipe had already been placed. Thus it was possible for the pipe crew to proceed up the street behind the digger, with no open trench left behind for later backfilling. In other words, the dirt excavated ahead of the pipe laying was immediately deposited in the trench where the pipe had been laid a short time previously. The material in the trench was later compacted by flushing.

More Details on Financing

To go back to the financing of the sewer project, the whole cost of some $98,000 was advanced from a reserve fund. It was agreed that the assessments would be on a benefit basis. The cost of the outfall sewer, serving all of the 250 present and future dwellings, amounted to $45,000. Each one would be charged with an equal share of this cost, or $180.

Those properties located in existing or proposed subdivisions where the local sewer mains were paid for by the developer, were assessed only for the share of the outfall sewer.

The remaining property, served by the laterals built by the Village, estimated to comprise 125 eventual connections, shared equally the remaining cost of the sewer construction. This meant that these 125 assessments included the $180 for the outfall sewer and $420, which was the share of the system cost exclusive of the outfall. This made a total assessment of $600 per tap, regardless of the frontage per dwelling.

It might be said, incidentally, that a good private sewage disposal system will cost nearly twice the amount of this total assessment.

This method of assessment divided the burden of carrying the sewer mains along frontages incapable of development. It also did not penalize the owner who had generous frontage for his dwelling, a thing to be encouraged. It was agreed that the sewer was as much benefit to the owner of a dwelling on a 100 ft. lot (the minimum allowed) as to the owner of a 300 ft. frontage.

While deferred assessments were made on all property, based on available building sites and minimum frontages, no one is required to pay for more than the actual taps connected to the sewer. This method is entirely fair to those who use the system. It does not penalize those who do not develop their frontages.

Payments vs Benefits

The only criticism which might be made is that the Village might not get back all of its investment, and some of the payments would be several years in coming back to the treasury. The real advantage is the elimination of a probable unsanitary situation in an area where sewage disposal by septic tanks would not prove satisfactory, and the entire Village benefits from such a program.

The contractor on this sewer project was O'Connell and Sweeney, Inc., General Contractors of Cincinnati, Ohio. The engineering was handled by the Village Engineering Department under the direction of the Village Manager. The job was completed in about four months.

Many of the existing dwellings on the system were immediately connected. The rules and regulations provide that no new septic tanks will be permitted in the sanitary district and when existing private disposal systems become a nuisance, they shall be abandoned and connections made to the sewer.

SIDE VIEW of sequence of operations. The trencher (extreme right) discharges dirt to conveyor in center. Conveyor at left is the final link in completing the fill. Note movable trough to control placing of dirt.

● COLD-MIX ROCK ASPHALT is used for skin patches, for general street repair, and for seal coatings on rough and badly worn surfaces.

SOLVING CHALLENGING

H. H. HESTER
Street Superintendent, Fort Worth, Texas

THE purpose of this article is to outline some of the challenging problems that have been solved, at least in part, by the Street Department of Fort Worth, Texas. Our city has some 255 miles of permanent types of paving, most of it placed 20 to 50 years ago, consisting of brick, concrete and various types of asphalt. In addition, there are 380 miles of inverted asphalt penetration, generally referred to locally as "shot" streets. Of these, 140 miles are single-course and 240 miles are double-course. It is these penetration type streets that have given us the most trouble.

Eight Days of Icy Weather Cause Breakups

Texas is generally known for its mild winters, which are not severe on these lighter-type pavements, but in February, 1948, the unusual happened. Ice stayed on the streets for eight consecutive days and nights, creating finally a maintenance problem never before experienced or even anticipated. Rain and melting snow penetrated many miles of old "shot" streets and froze. When the thaw came, the city had some 250 miles of these streets which quickly developed holes. As soon as the weather permitted, it was necessary to put the entire Street Department at work repairing these holes by filling them with gravel, using so far as possible material of the same type as was used originally in the base of the particular street.

This temporary repair work sufficed until the Maintenance Division could begin permanent repairs. The forces available for this work consisted of a maintenance supervisor, a foreman, 8 distributor operators, 2 firemen, 12 truck drivers, a loader operator, a roller operator and 35 laborers. The equipment used included four asphalt distributors, (two 1,000-gal. Etnyre and one 1,000-gal. Littleford, both truck mounted, and one 600-gal. Rosco, trailer mounted); a 1-yd. Hough loader; a 5-ton Buffalo-Springfield tandem roller; and 12 1½-ton trucks (six Ford, four Chevrolet and two Dodge). There was assigned to each distributor, two operators, three dump trucks and five laborers. All of the men of the Maintenance Division were experienced in this type of maintenance work.

Procedure in the work was as follows: One laborer cleaned the hole to be patched, using a push broom; two rock men placed the base material, which was graded with ¾" to ⅜"; OA 135 asphalt was then applied; two men covered the asphalt with chats or pea gravel, all passing a ⅜" screen and retained on a 10-mesh. OA 135 asphalt, commonly used in this area, has a penetration of 120 to 150.

The patches varied from 2 to 6 ins. in depth and from 6 to 18 ins. in width. A tack coat was used on all patches over 4 ins. in depth. Throughout, care was taken to place the patch material at just the proper elevation, for if a patch is too high, a rough spot results and the material around the edge of the patch tends to work loose. Care was also necessary to apply only the correct amount of asphalt, as too much asphalt causes fat spots which quickly become rough and irregular. We have found that a properly constructed path of this type gives good service, as the materials used are better than those used in the original construction. Naturally, an experienced and well-trained crew is an absolute necessity in this type of work.

Keeping Down Costs by Careful Planning

In order to keep costs for patching and resurfacing to a minimum, the Street Department operates its own crusher, a jaw-type Austin-Western with a capacity of 50 tons per day. We obtain our stone from many sources: Contractors haul broken rock, concrete and brick to the crusher without cost to the city; and the Street Department brings in oversize rock from streets that are excavated or graveled. Three sizes of stone are produced: ¾" to ⅜"; ⅜" to 10-mesh; and a dust that contains approximately 50% of fine aggregate. This dust is used primarily to cover bleeding streets during the summer months, and also as a cover material in crack-pouring work.

There were many miles of streets

STREET MAINTENANCE PROBLEMS

Eight days of freezing weather brought Fort Worth's maintenance problems to a head. Here is how they were solved.

that were rough and irregular, and on these a different method of maintenance was needed. These streets were scarified, and the old surface worked into the existing gravel base, which assists in stabilizing the base material. A good grade of road gravel was then added to provide the necessary additional thickness for the base and to increase the crown of the roadway. This increased crown is considered important on this type of surface as it facilitates rapid shedding of water from the street surface. After this work had been done, the street was reshaped, waterbound and opened to traffic for 10 days to two weeks. During this period a water tank truck was used to keep the street well sprinkled and moist; and the street surface was checked carefully for weak spots. If any developed, they were remedied, usually with new materials.

At the end of the curing or compaction period, the street was bladed, rolled, and surfaced with double course asphalt penetration. The first application of asphalt was 0.4 gal./sq. yd. of OA 135. This was covered with crushed stone or pea gravel, all passing a ⅜" screen, applied at the rate of 60 to 65 sq. yds. per cu. yd. A spreader box was used to apply the stone or gravel; and after it had been spread, the old-fashioned split log drag, shod on the bottom with a 1½" angle iron was pulled over the surface. Care was exercised in this work and an amazingly smooth job resulted. Previously we had rolled these surfaces with a 5-ton tandem roller; however, our experience has proved a pneumatic roller to be preferable.

PATCHING penetration streets: Applying bitumen to the aggregate.

After the surface was rolled, a second application of the same asphalt was used, 0.35 gal. per sq. yd. This was covered with a torpedo gravel having a maximum size of ¼", which was applied so that a cubic yard covered 75 to 80 sq. yds. After this torpedo gravel was spread, the surface was dragged and rolled, as with the first application, and the street was then opened to traffic. The final dragging added very little to the quality of the street, and the careful construction of the first course was usually sufficient.

In all, during the summer of 1948, the Street Department tore up, added gravel to, and resurfaced 11 miles of "shot" streets.

Problems in Financing Street Improvements

In some cases, "shot" streets can be maintained by placing a seal coat. We use this method of maintenance on such streets that have worn thin, but are still fairly smooth. In this operation, a rotary sweeper is first used and the street is thoroughly cleaned. An application of 0.25 to 0.30 gal. of OA 135 asphalt is made and a cover material of chats or torpedo gravel, all passing a ¼" screen, is placed, using a spreader box. This is spread so as to give a yield of 90 to 100 sq. yds. to the cubic yard of material; it is then rolled with a 5-ton tandem roller. Over 9 miles of streets were treated in this manner during 1948. We have found that such treatment prolongs the life of the surfacing, not only by sealing water out of the base, but also by adding new life to the asphalt that has been in place for many years.

Since it is impossible to get property owners interested in helping to repave wornout streets with a permanent type of pavement, we are convinced that a method of maintenance, such as we use, is the only way out. This type of maintenance is costly, and many cities must have additional revenues for this work. Texas cities do not receive any of the gasoline tax revenue for street maintenance, nor do city owned cars and trucks have any exemption. In our state, 60% of the cars and trucks that pay the gasoline tax, and help wear out paved streets, never leave the city limits.

We experimented last summer with a seal coat material produced by the Uvalde Rock Asphalt Co. of San Antonio. This material is called "Kover Mix, Type B." The mixture is fluxed with 1½% to 2% of Fluxoil, so that the flux covers all particles in the mix. We used this material on some of our old streets that were very badly worn and rough. A tack coat was first applied to the surface, using 0.18 to 0.20 gal. of RC-2 per sq. yd. The cover material was loaded into trucks with a mechanical loader and placed on the street with a spreader box. The yield of the material was approximately 60 sq. yd. to the cubic yard. After spreading, the same type of drag was used as described previously, giving a very smooth job. At first, we tried this material at the rate of 85 sq. yds. per cu. yd., but found this was too thin. The cost of this method of treatment was 12¢ per sq. yd. Though used on streets that carry considerable traffic, and placed early in the season, no sign of raveling or deterioration has been noted.

Before leaving this subject of maintenance of asphalt penetration streets, it should be stated that the specifications of the city do not any longer permit construction of this type of surface. We now require 9 ins. of compacted gravel base, a concrete curb and gutter and a triple course asphalt surface treatment. For a 50-ft. front lot on a street 30 ft. wide, costs will be about as follows: For the gravel base, $35; for the curb and gutter, $70; and for the surface treatment, $25. This is a total of $130 for a 50-ft. lot for one half the width of the street. The city cuts the street

to grade, and furnishes the gravel for the intersections and alleys; the property owners pay for the remainder of the gravel, the curb and gutter and the surface treatment.

This type of pavement is suitable for residential areas where traffic is light, but it is not recommended for main thoroughfares or streets that carry heavy traffic. Permanent types of pavements should be used in such places.

Permanent Surface Maintenance Procedures

In the maintenance of permanent type bituminous pavements, rock asphalt, or cold mix asphalt is used in many cases, since these are especially adapted to skin patching. After a tack coat, the material is raked into place and rolled with a 3-ton roller. In order to prevent raveling, the edges of the patch are carefully hand tamped and painted with a mixture of OA 135 asphalt and kerosene, the same mixture that is used for the tack coat. On streets where patches from 2" to 4" in thickness are necessary, hot mix asphaltic concrete is used. This is purchased locally from a contractor for approximately $5.25 a ton at the plant, and is put in place by hand and rolled with a 5-ton tandem roller. During the summer of 1948, the City purchased, in place, some 10,000 tons of hot mix asphaltic concrete surfacing. This was placed in two-course strips on several of the City's main thoroughfares. A strip 20' wide was placed down the center of a 30-ft. street, and a 40-ft. strip was placed on 50 and 60-ft. streets.

Limited funds, and the quantity of work involved, necessitated this "strip" resurfacing. The portions of the street not resurfaced are used for on-the-street parking, and are not considered a part of the traveled roadway. The "in place" provision of the purchase included laying the 1½" thick surface in two layers, using an asphalt spreader and rolling the mix with an 8 and a 10-ton roller. The purchase was made on a bid of $8.65 per ton in place. On streets that are surfaced from curb to curb, the City pays one-half the cost of the resurfacing and the property owners the other half.

On brick streets where failures occur in the base, bricks are removed, a new concrete base is poured and the bricks are cleaned and put back in place. On old brick streets that become rough, the skin patch method is used, with cold mix Rock Asphalt as the patching material. An unusual experiment was tried on old concrete pavement in March, 1948. Some of the old concrete pavements, that were laid with the help of the WPA in 1934 and 1935, cracked very badly during the severe cold wave. Since funds were not available to remove all broken areas and replace them with new concrete, the bad places were cleaned and an OA 135 asphalt was applied and covered with pea gravel. The total thickness of the material placed varied from ½" to ¾". This experiment proved successful, for the asphalt sealed the water from the subgrade, and the cover material leveled up the depressions in the street caused by the breaking and settling of the concrete. Where failures occur on the better concrete pavements, the broken concrete is removed and new concrete 7" to 8" in thickness is laid. An extra thickness of concrete is worked under the edges of the adjacent slabs to provide support.

How the Utility Cut Problem Is Handled

The Street Department handles all street cuts for the Water Department, a charge being made to cover the actual cost of the work. The city, prior to January 1, 1949, required all plumbers to repair their own street cuts. Ft. Worth has experienced a rapid growth during the past few years, and so many street cuts were necessary that the contractors making such repairs could not keep up with the work to be done. Numerous complaints were made to the Street Department. An amendment to the Plumbing Ordinance was recently passed, by the Council, requiring all plumbers to deposit with the city sufficient funds for repairs before a permit for a street cut is issued.

The charge for repairs is $2.00 per lineal foot on permanent type paving; $1.20 per lineal foot on asphalt penetration streets; $0.70 per lineal foot on graveled streets; and $5.00 per cut on dirt streets and alleys.

When final inspection has been made on plumbing lines, the Plumbing Inspector notifies the Street Department, in writing, that the plumbing work has been completed. The plumber is required to backfill the ditch with dirt in 6" compacted layers and to leave the dirt from 2" to 3" above the level of the surrounding area. A week or ten days is allowed for the ditch to settle. After the "settlement period," the Street Department dispatches a crew to the cut to place the surfacing. In the case of an asphalt penetration street, the cut is excavated to a depth of 12" and a good grade of road gravel is placed in the excavation. In the case of permanent type paving, a concrete base is run, using Incor Cement in order not to have the cut barricaded any longer than necessary. Two or three days after the base has

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LEADERS IN THE PUBLIC WORKS FIELD

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LINN H. ENSLOW

President of the American Water Works Association, member of many other technical associations and societies, Linn H. Enslow is widely known in sanitary engineering circles. Since 1931 he has been editor of Water and Sewage Works, and since 1934 a vice-president of Gillette Publishing Co. A graduate of Virginia Polytechnic Institute, his previous experience included work with the Maryland and Virginia Health Departments; and from 1925 to 1931 he was research engineer for the Chlorine Institute.

MOVING A STREAM BED GIVES
Better Bridge Site

● ***ERECTING FIRST BARREL** of Multi-Plate pipe arch bridge, using a truck-mounted crane. Footings in place for wing and end walls. Note reinforcing steel already placed.*

CARL H. BAUER
County Engineer, Montgomery County, Ohio

DANGER to the traveling public and rising maintenance costs were the two major factors which influenced Montgomery County, Ohio, to replace one of its oldest bridges in the summer of 1948. Built in 1901, Bridge No. 7, Madison Township, had not been designed to carry the heavy traffic now using the Westbrook Road, a main county route which serves as a circumferential road north of Dayton. Suburban housing developments in this area have resulted in a greatly increased daily traffic load. This traffic increase gave the bridge more severe service than ever before, causing maintenance costs to soar on the old structure. In addition, it increased materially the frequency of accidents due to the poor alinement of the bridge and the steep approaches.

This old steel truss bridge had a 54-foot span and a 15-foot clear lane for traffic. Treated oak stringers supported the wood plank flooring. The original abutments and wingwalls were of stone masonry, but had been undermined by the creek years ago and had been encased and extended in depth with concrete. Records show that the wood plank flooring on the old bridge had been replaced every 4 years in its later life. In addition, frequent repairs to bridge members, particularly the end posts, were necessary because of damage resulting from accidents. At the time the structure was replaced, extensive repairs were needed on the 46-year-old structure.

Westbrook Road is centered on a section line to a point near the old bridge. There it curved 26 degrees to the right and continued for 370 feet where it made a 72-degree turn to the left to cross the bridge. Some 250 feet farther on it joined the section line again with a 46-degree turn to the right. In the distance from the first turn to the bridge the road dropped in elevation some 20 feet. This combination of poor grade and alinement caused many accidents.

Aerial view, old and new bridges, showing improved alinement.

Planning the New Work

A survey was made in August, 1947, to determine the best method of remedying the situation. It was found that in addition to building a new bridge and changing the road alinement, it would be necessary to relocate some 1,800 feet of the stream. This involved moving approximately 10,000 cubic yards of earth to create a channel with an average bottom width of 40 feet and side slopes of 2:1. The new design eliminated the curved approaches which had been a hazard to road users.

Several preliminary designs were drawn up using various types of structures. These were studied for cost and availability of material, and it was decided that Multi-Plate Pipe-Arch would satisfy the design features and at the same time result in substantial savings for the county. A design and an estimate were submitted to the board of County Commissioners, who approved them with Multi-Plate specified as the material to be used and with the major portion of the work to be done by county forces.

The design of the new bridge called for three barrels or arches, each having a span of 15 feet 9 inches, a rise of 9 feet 7 inches, and a length of 46 feet. These were to be skewed 55 degrees off the new centerline of roadway and spaced 5 feet apart. The bottom and corner plates of each barrel were to be

made of 1-gauge metal while the remaining plates were 3-gauge. This design provided extra thickness of metal in the bottom where stream erosion is most severe. Headwalls and wingwalls for the bridge were to be constructed of reinforced concrete. These would be 15 feet 4 inches in height and require over 200 cubic yards of ready-mixed concrete.

Construction Procedures

Armco materials were purchased and work began on the project in October, 1947. County forces and equipment were used to clear the site of the new bridge and divert the stream around the working area; meantime, work was being pushed on re-alining the channel on both sides of the project. When the footers had been poured and the bed for the structure prepared, a contract was let to the John E. Little Company of Dayton, Ohio, for erection of the arches.

A total of 384-man-hours of labor and 96 hours of equipment and operator time was expended in erecting the three barrels at a cost of $79.00 per foot of barrel for labor and material. During the period of erection, the whole job was washed out four times by unseasonable rains, causing unexpected delays and additional expense.

When the barrels were completed, the spandrel walls and pilasters were formed and poured, using ready-mixed concrete. Granular backfill was placed between the arches to a height of 6 feet 6 inches above the inverts. As the material was placed, a pneumatic tamper was used to compact this fill under the haunches and between the barrels. The remainder of the fill was placed in layers and compacted by the hauling equipment up to the elevation of the new roadway. As soon as sufficient fill had been placed on the structure to make it secure, the diversion channel was filled and the stream was forced to flow in the new channel and through the structure.

The Finished Job

A 20-foot roadway with two 8-foot shoulders was built over the bridge. The road surface on the bridge and approaches, totalling about 3,400 square yards, was treated with MC-O at the approximate rate of 0.5 gallon per square yard. A wearing course was then placed over this area using 0.35 gallon of MS-2 and 30 pounds of number 6 stone per square yard.

The slopes and berms of the new road were graded and seeded, and 1,500 lineal feet of Armco Flex-Beam guard rail were installed shortly after the structure was opened for traffic. This completed the project approximately 8 months after work was started.

During the period of construction for the new bridge, the County Engineer's forces continued to carry on their routine duties and perform special tasks. These activities included maintaining approximately 500 miles of road, applying a normal surface treatment to 165 miles, and performing the necessary patching operations during the spring of 1948 after a severe winter.

A Summary of the Job and Its Cost

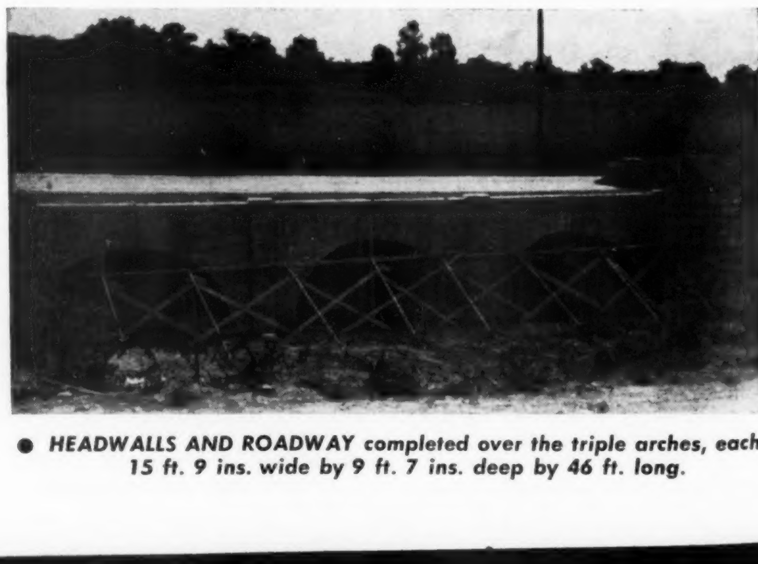
To summarize the steps of the project, the following operations were performed:

1. Acquiring the necessary property for the right-of-way.
2. Moving 15,000 cubic yards of earth.
3. Replacing a 54-foot bridge with Armco Multi-Plate pipe-arch.
4. Building forms for headwalls and wingwalls and pouring 200 cubic yards of concrete.
5. Grading and resurfacing ⅜ mile of roadway.
6. Installing a 76-foot corrugated metal pipe culvert.
7. Erecting 1,500 feet of guard rail.
8. Grading and seeding 90,000 square feet of slope and berms.

The total cost to Montgomery County for the entire project was $52,000, an estimated saving of $12,000 over the next cheaper way of performing the job. Of the total cost, the multi-plate accounted for approximately $13,000.

The supervision of the project was performed by the author with the assistance of R. O. Eisenlohr, Bridge Engineer. A. F. McCallum directed the work of erecting the arches for the John E. Little Company. Montgomery County Commissioners in office at the time of the job were John E. Brumbaugh, Harry J. Munger and John F. Ahlers.

● ***MULTI-PLATE ARCHES** in place. Note anchor bolts in ends of barrels and beginning of form work for right wing wall.*



● ***HEADWALLS AND ROADWAY** completed over the triple arches, each 15 ft. 9 ins. wide by 9 ft. 7 ins. deep by 46 ft. long.*

A portion of the trickling filter at Ridgewood. Most effective psychoda control was obtained by recirculating BHC through the filter, dosing tank and final clarifier for 12 hours.

Successful Filter Fly Control

JOHN HOOD

Superintendent, Sewage Treatment Plant
Ridgewood, N. J.

THIS is essentially a progress report on Psychoda control work at the Ridgewood plant over the past ten years. Our filter is of the "standard" type, 0.6 acre in area, 5½ ft. deep and with concrete walls extending 15 ins. above the surface of the basalt media. Constuction is such as to pemit flooding.

The flooding technique, developed by Headlee, were practiced for eight years with varying success. In view of the more general present-day interest in the use of organic compounds which are specific against insects, reference to control by inundation will be brief. Our principal objections were the adverse effects on filter operation. Moreover, even with a weekly or twice-weekly flooding schedule, fly control was not fully effected.

A study of the record of psychoda control by DDT was made. The reports by Carollo and Brothers on the work done at Army installations *(Sewage Works Journal, March, 1946)* referred to high rate filters. The information issued by Proportioneers included data on control measures at a low rate filter, at which there was no interruption of filter operation or serious impairment of the effluent quality.

Based on these previous practices, we determined to apply 1 ppm of DDT (net weight), based on a sewage flow of 3 mgd, applying the DDT over a period of 2 hours, which gave us a concentration at the nozzles of 12 ppm. With this, 20 days of 95% control was effected, the remaining 5% control being accomplished by hand-spraying at weekly intervals, the exposed wall surfaces and marginal areas of media not covered by the nozzle sprays. Pennco 34% DDT emulsion concentrate was used. There was no interruption to filter operation, the only contact time provided being that afforded by the rest period between the operation of the automatic siphons.

After 24 days, the number of psychoda present indicated the need for another treatment. This time 0.5 ppm, computed as before, was applied. The results were disappointing and after 5 days the work had to be repeated using the original effective application of 1 ppm.

Computing the DDT Required for Control

The articles in *Sewage Works Journal* were not entirely clear in respect to concentrations, pounds per acre-foot and "rest" or contact time. Re-examining our work on the basis of pounds of DDT per acre-foot, we found that, due mainly to structural differences, we had applied 8.3 pounds per acre-foot, while Lt. Brothers had applied 15 pounds.

Thus for effective control, consideration must be given not only to a minimum concentration expressed as ppm of net weight of DDT based on the total daily sewage flow, but also to the hours over which the computed dosage is applied, and this gives the concentration of DDT at the nozzles or distributors. The contact period also possibly affects the application. In short, for each individual installation there has to be a reduction to practice of the data. At the moment it appears that 1 ppm applied, without interruption of plant operation, for a period of 2 hours, may be used as a basis for initial control tests. Computations will be as follows, using Pennco 34% DDT emulsion, weighing 8.77 pounds per gal. and containing 2.98 pounds net of DDT per gallon: 1 ppm for 1 mgd at 8.34 pounds per gallon, there will be required 8.34 pounds of DDT, net. Then 8.34 ÷ 2.98 = 2.8 gals. or 10.599 liters. At Ridgewood, our flow is 3 mgd and we required 8.4 gals. or 31.797 liters. Our dosing tank capacity is 10,000 gals., giving approximately 12 discharges per hour, and for two hours, 24 discharges. Thus, there was required for each dosing tank full 31.797 ÷ 24, or 1.324 liters. This yielded an actual concentration at the nozzles of 12 ppm and an acre-foot loading of 8.3 pounds.

Some of the references indicated that extension of the application

(Continued on page 80)

PUBLIC WORKS DIGESTS

● *This section digests and briefs the important articles appearing in the periodicals that reached this office prior to the 15th of the previous month. Appended are Bibliographies of all principal articles in these publications.*

THE WATER WORKS DIGEST

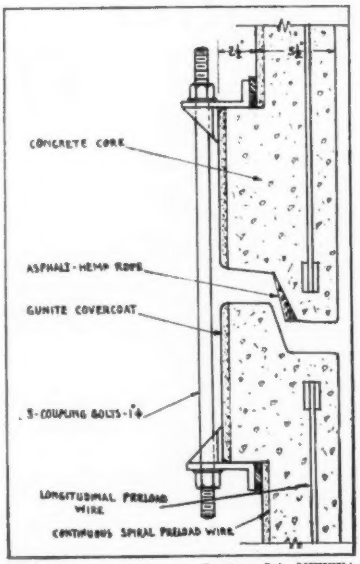
Quality of Water From Individual Wells

An investigation of the quality of water furnished by the 81 wells in a New Jersey rural village of 100 families, 71 wells being dug wells about 30 ft. deep, 7 driven wells about 40 ft. deep, and 6 drilled wells 92 ft. deep, led to the conclusions that the average dug well is three to four times as likely to show pollution as a driven or drilled well; that, on the average, difference in bacteriological and chemical quality of well waters between dry and wet seasons is not significant; and that infiltration of surface waters into dug wells contributes to the increased incidence of pollution, and to the greater variation in chemical composition for individual well waters.

Harold E. Orford—"Study Shows Quality of Individual Well Supplies"; PUBLIC WORKS, April.

Prestressed Concrete Intake Pipe

In designing a new river intake for the city of Montreal, Canada, the city's engineering staff specified four 84" concrete pressure pipe extending 2,000 ft. into the river, to be encased in a heavy concrete cover to protect them from ice and currents. Bids received included one for prestressed pipe, which was accepted, although no such pipe without a steel diaphragm had ever before been made on this continent. Each pipe as made was 18 ft. long, with 5½" wall, prestressed both circumferentially and longitudinally. Twelve pairs of steel longitudinal prestressing wires induced a compression of 188 psi, and the continuous spiral steel circumferential wire, at 0.63 in. spacing, induced a stress of 725 psi. The longitudinal wires were cast in the concrete, and stressed by means of stressing nuts at one end, which elongated them about ½". The circumferential wire was wound on under a regulated stress. The prestressed pipe then was covered with about ¾" of gunite. Five percent of the pipes were tested under 50 psi hydrostatic pressure. One pipe was tested to 87 lb., when it cracked, but when the pressure was released the crack closed and showed no leakage under 50 lb. pressure applied again. The concrete used had practically zero slump, and tested over 4500 psi at 28 days. It was cured for 72 hr. at 90-100° F and 100% humidity. Each pipe took about 10% less concrete and 3,000 lb. less steel than would the conventional type previously used.



Courtesy Jnl. NEWWA

JOINT details for prestressed pipe.

R. M. Doull—"Production of 84-Inch Prestressed Concrete Pressure Pipe for City of Montreal"; *Jour. New Eng. W. W. Ass'n,* March.

Jute for Pipe Joints

The Committee on Water Works practice of A.W.W.A., in its annual reports, makes few recommendations. Among them is the deletion of jute or hemp as an acceptable material for use in jointing bell-and-spigot pipe. "A variety of other materials available, several of which are being widely used, means that the elimination of jute from the acceptable list will pose no problem for the waterworks construction field."

Other changes proposed are the preparation of specifications for "wet barrel" or "California type" hydrants, and for asbestos-cement pipe.

"Report of the Committee on Water Works Practice"; *Jour. Am. W. W. Ass'n,* March.

Value of Consumer Complaints

Consumer complaints of all kinds should be considered carefully by management; they may call attention to real defects in service. For instance, complaints of low pressure may indicate unrealized inadequacies in transmission or distribution facilities. Complaints of odors, dirt or sand in the water may indicate that flushing of dead ends is necessary or that treatment equipment is not functioning properly. Behavior

of personnel that leads to complaints may affect consumer goodwill. Other complaints are those due to settling of street pavement over trenches, failure to notify consumers of temporary main shutdown, objections to appearance of or vibrations from pumping plants.

Laurence L. Camy—"The Value of Consumers Complaints"; *Jour. Am. W. W. Ass'n*, March.

Seismic Reconnaissance

There are two methods of seismic prospecting of subsurface conditions—the reflection method and the refraction. The latter is used for depths less than 200 ft. A buried charge of dynamite is exploded and the wave created travels with different velocities through different materials; say 1,500 to 3,000 ft. per sec. through fine, dry sand, 3,000 to 6,000 ft. through wet sand or gravel. The author uses 12 sesimometers spaced 5 ft. to 100 ft. apart, connected by cable to a recording truck where each records photographically the time it is reached by the wave.

This method is not adapted to small areas; the length of the line of seismometers should be at least 3 times the depth to rock, and generally extend several hundred feet further in each direction. Its real advantage in reconnaissance for ground-water development lies in its speed and economic saving. It should be followed by test drilling and sample-taking.

Daniel Linehan—"Seismic Reconnaissance for Ground-Water Development"; *Jour. New Eng. W.. W. Ass'n*, March.

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Insurance Problems of Water Works Companies. By *Charles C. Goodrich*, insurance adviser. March, Pp. 45-56.

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PUBLIC WORKS DIGESTS

THE SEWERAGE and Refuse Digest

Operating Sanitary Fill

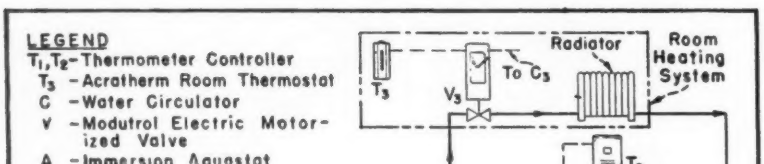
Winnetka, Ill., has completed a second year of its refuse disposal by sanitary fill, and the records show a reduced unit cost of operation in spite of an increase in the wage scale and in equipment maintenance. This is partly due to a 13% increase in the volume of material handled. But an important factor in reducing cost was a change in operation routine. Formerly a trench was filled beginning at the far end and raising the fill to 5 ft. above the original ground surface at one operation. Last year, filling of the trench was begun at the end nearest the access road and brought up to ground surface only for its full length, and covered with about 6" of dry material. Then the additional 5 ft. was placed, beginning at the far end, and was covered with 2 ft. of earth from the trench being dug for the succeeding fill. Thus the truck and tractor placing and compacting the fill never operate down in the trench, which may be very soft; the dragline that excavates the trench operates only during the placing of the second lift; the sloping operating face is shorter; and better compaction of the lower part of the fill is obtained. The cost last year was $0.159 per cu. yd., not including anything for supervision or office overhead.

Robert L. Anderson—"New Methods Improve Sanitary Fill Operation"; *PUBLIC WORKS*, April.

Instruments in Treatment Plants

In operating sewage treatment plants, the precise measurement and control of such factors as flow, temperature, liquid level, pH and pressure yields large dividends in the conservatoin of fuel, time and material. In Glens Falls, N. Y., an oil-fired boiler is operated in parallel with a gas-fired unit to insure adequate hot water for digesters, building radiators, drying beds, etc. A temperature controller regulates the supply from the oil-fired boiler, if any, to maintain a temperature of 180°; another mixes return water with boiler water to maintain 130° water for the digesters. Circulators are controlled by aquastats in the digester return water to prevent overheating of the sludge. A 3-pen recording thermometer records the temperatures of the input water and of the return water, and a meter measures and records the amount of water circulated.

A. O. Pearson—"Sewage Plant Instruments—What They Can Do"; *American City*, April.



Courtesy American City

● *WATER-CIRCULATING controls for combined oil and gas-fired boiler.*

The Industrial Wastes Problem

There is no comprehensive knowledge of how many waste-producing industries there are in the country, and how much waste is polluting the country's streams or being treated in individual or municipal plants. Inquiry of all the state boards of health obtained few definite figures—some did not even guess, although a few listed such plants in detail and classified by types. Nevada and New Mexico report no problems—what few liquid wastes there are reach no streams but are absorbed by the dry soil and evaporated. Approximate figures of the numbers of plants producing polluting wastes are reported as follows: Alabama, 400. Arkansas, 252. California, 2,500. Florida, 76. Connecticut, 438. Illinois, 842. Indiana, 488. Kentucky, 279. Ohio, 572 (not including many discharging into sewers). Pennsylvania, 5,000. Kansas, 200. Minnesota, 2,309. Mississippi, 56. Iowa, 1,318. New York, 830. S. Dakota, 569. West Virginia, 85 (plus 85 small slaughter houses and 140 coal washeries). Montana, 38. No. Carolina, 600. Virginia, 225. Massachusetts, 2,000. Tennessee, 176 plus 154 to municipal sewers. Michigan, 330. New Hampshire, 100. Wyoming, 25. No. Dakota, 98. The total for these 26 states is over 20,000.

The classes of industry which are the leading factor in the pollution problem were named by 31 states. Taking the three leading ones in each state, we find that 18 states include milk processing; 11, canning and other vegetable processing; 10, pulp and paper mills; 9, meat processing and slaughter houses; 8, textile plants; 5, chemical plants; 5, beet sugar plants; 4,

oil refining; 4, metal plating. Others include coal mining, distilleries, tanneries, dyeing, phosphate mines, machine plants, breweries, petroleum products, non-alcoholic drinks, and lumber.

"Industrial Wastes Treatment—A Review and Forecast"; *Sewage Works Engineering*, March.

Air Pumping Of Sewage

Owing to the absolute flatness of its area and the high water table, it is desirable to place the treatment plant of Clewiston, Fla., entirely above ground, and it is necessary to pump the sewage at eight points. Because the frequent tropical storms often cause electric power outage, electric pumps were not considered reliable; the practical problems of operating eight widely scattered gasoline pumping units seemed to rule these out, and pumping at all stations by compressed air supplied from a central compressor station was adopted. This central compressor is to be electrically operated, with a gasoline driven standby of the same capacity —88 cfm. Air will be distributed through a network of 2" and 4" c. i. pipe, all to be tested hydrostatically to 150 psi; then drained and tested pneumatically to 120 psi. Each station will be placed under ground and contain duplex pneumatic ejectors. Partly to minimize the lift of the pumps, and partly because there is no stone in south Florida suitable for filter media, activated sludge was chosen instead of biofiltration.

Walter J. Parks, Jr.—"Hurricane Hazards Dictate Air Pumping of Sewage"; *Sewage Works Engineering*, April.

Sewerage for Trailer Parks

There are over 500,000 trailer coaches in the United States, about half of them parked in some 7,000 trailer parks. To encourage purchase of trailers, the Trailer Coach Mfrs. Ass'n. is endeavoring to raise the standard of trailer parks. Of 4,000 of these inspected, only 1,500 were approved from the point of view of sanitation. The Association furnishes park owners with information concerning sewage treatment, using as a basis 20 to 35 gpd per capita and 3 persons to a trailer. The BOD is estimated at 0.11 lb. per person—less than the customary standard because many tenants will use facilities outside the parks, garbage will be less, children will be at school, etc. Therefore the BOD is estimated to range between 380 and 660 ppm. For toilets, the flush tank toilet is not practicable, the Pullman type is unsatisfactory, and the marine type with a hand-operated pump seems to be the best.

Tom H. Forest—"Sewage Treatment for Trailer Coach Parks"; *Midwest Engineer*, March.

Photoelectric Estimation Of Suspended Solids

Many recent articles have attested to the value and limitation of photometric determinations. A study to determine a satisfactory method of estimating the total suspended solids in sewage used a Waring Blendor for uniform particle distribution and a photometer for recording the transmission of light. It was concluded that:

Photelometers operating on compensating or constant current and sample compartments which permit maximum scattering of light are readily adaptable to a satisfactory estimate of the total suspended solids of sewage. Samples subjected to the photelometer tests should first be processed by some type of homogenization which will assure reasonably uniform particle distribution and range of size. Moderate homogenization of sewage containing coarse par-

ticles or activated floc is a desirable adjunct in obtaining representative samples for the Gooch test.

Lloyd R. Setter—"Photoelectric Estimation of Suspended Solids in Sewage"; *Sewage Wks. Jour.*, January.

Treatment Of Rum Wastes

A distillery in Massachusetts producing rum discharges its wastes into the municipal sewer system. This produced trouble at the treatment plant, chiefly sealing of the sand beds, and the State Health Dept. forbade the industry to dispose of its waste into the municipal sewers until some remedial measure had been developed. The problem was studied at the Sedgwick Laboratories of M.I.T. It was thought that high-rate trickling filters offered the most promise, and tests were made with one of the Biofilter type, using preliminary settling, first stage filter, intermediate settling, second stage filter and final settling. Mixtures of sewage containing 1% of the distillery waste were satisfactorily treated, using a recirculation ratio of three volumes of final effluent to one volume of sewage. The influent B.O.D. averaged 485 ppm and the final effluent B.O.D. averaged 19.7 ppm. A 95.7% removal was accomplished. The loading on the filter was at the rate of 2,590 lb. of B.O.D. per acre foot.

Clair N. Sawyer and Earl J. Anderson — "Aerobic Treatment of Rum Wastes"; *Water & Sewage Works*, March.

Treatment of Wool Scouring Wastes

From the standpoint of stream pollution in Massachusetts, wool scourings present one of the most important industrial waste problems. The wastes are much too concentrated for normal biological treatment without great dilution and many methods of chemical coagulation have been proposed, recently the use of $Ca(OCl)$. Study at the Lawrence Experiment Station indicated that the coagulation caused by the calcium ion is the most important part of the improvement from the stream pollution standpoint. In using calcium chloride, it was found that, when the pH of the waste was reduced to somewhat below 8, floc formed almost instantaneously and settled rapidly. It is therefore advisable to reduce the alkalinity, and carbon dioxide effects this satisfactorily; adding two or three times the volume theoretically required to react with the carbonates and hydroxyl ion present seeming to be necessary. Such addition made possible 20% to 50% reduction in the amount of calcium chloride used, or obtaining much more satisfactory coagulation with a given amount. This process was found to work well whether the mill used detergent or soap scouring. It removed practically all the suspended B.O.D. but not the dissolved; also practically all the suspended solids, including the fats. The sludge that was formed dried quite readily on sand; vacuum filtration probably is feasible, but not centrifuging. If further removal of B.O.D. is necessary, biological treatment seems to offer the most economical means. It seems probable that sufficient quantities of marketable grease can be recovered from wool scouring wastes to cover at least the cost of chemicals and operation.

Joseph A. McCarthy—"A Method for Treatment of Wool Scouring Wastes"; *Sewage Works Journal*, January.

Methods of treating wool scouring wastes include centrifuging (of little practical value), chlorine treatment (not now used), acid cracking, the calcium hypochlorite process, and the calcium chloride process. Either of the last three produce satisfactory results. Acid cracking produces objectionable odors and an acid effluent, and the amount of residual polluting matter is many times that of sewage. The calcium hypochlorite and calcium chloride treatments produce little odor and an effluent of satisfactory pH, but the residual B.O.D. usually ranges between 800 and 1,000 ppm. Costs are of the order of $0.77 per 1,000 gal. for acid cracking, $2.12 for hypochlorite treatment, and $1.65 for calcium chloride.

Stuart E. Coburn—"Comparison of Methods for Treatment of Wool Scouring Wastes"; *Sewage Works Journal*, January.

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Unique Sludge Digesters in Germany. By *C. E. Keefer*, Dep. Sew. Engr., Baltimore, Md. April, P. 148.
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PUBLIC WORKS DIGESTS

THE HIGHWAY and Airport Digest

Widening Narrow Roads

Some 50% of all improved road surfaces remain 18 ft. or less in width, although thousands of miles of all types of old pavements have been widened. For present-day traffic a width of 24 ft. is desirable. Recently there have been developed special equipment for excavating the earth shoulder to the exact width and depth required, piling the dirt so removed on the side away from traffic, and narrow-wheel rollers for compacting the subgrade and the asphalt paving material, and special distributors for placing such material. No matter how thin the resurfacing, it should be placed in two or more layers, both because of the greater smoothness resulting and also because of the more uniform and complete sealing of the surface.

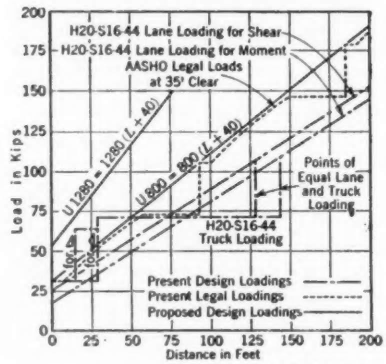
Bernard E. Gray—"Future Trends in Highway Development"; *Asphalt Institute Quarterly*, April.

Costs of Highway Maintenance

On the basis of data collected by the Public Roads Administration and the Highway Research Board from the 48 states and 402 counties, and also 28 counties that have a high quality of maintenance performance, the author finds that, per 1,000 miles of highway maintained, the annual expenditure averaged $655,000 by states, $197,000 by the 28 selected counties, and $169,000 by the 402 counties. The much higher costs for state highways were due to the greater weight, quantity and speed of traffic. The states had spent $668,450 per 1,000 miles for purchase of equipment, the 28 selected counties $253,450, and the 402 counties $196,000. The 28 counties had 4.3 hp of equipment per mile of road and the 402 counties averaged only 2.7 hp; which, the author thinks, accounts for the good quality of maintenance in the selected counties.

Analysis of the equipment inventories submitted by the 402 counties shows that the average number of each type used per 1,000 miles of highway was as follows:

Type of Equipment	Number of Units	Estimated Horsepower	Estimated Cost New
Automobiles and pickups	2.0	182	$ 3,200
Air compressors	0.3	16	900
Motor graders	7.2	374	57,600
Tow graders	2.5		6,250
Loaders	0.8	27	2,000
Mixers	0.5	14	900
Mowers	1.5		2,250
Crushing plants	0.2	22	3,000
Displacement-type snow plows	3.9		3,900
Rollers	0.8	30	4,000
Power shovels and cranes	1.3	98	16,900
Crawler and wheel-type tractors	4.4	253	36,300
Trailers	0.4		1,000
Trucks, all types	16.9	1,691	51,300
Welders	0.1	5	260
Unclassified equipment	3.1	2	6,430
Total	45.9	2,714	$196,190



Courtesy Civil Engineering

Highway bridge loading diagrams.

J. S. Bright—"Reducing Maintenance Costs on County and Local Roads"; *Better Roads*, March.

Design Loading For Highway Bridges

The rapid evolution of highway trucks, with trailers and semitrailers attached, has imposed upon bridges a heavy burden beyond the expectation of bridge engineers. That the present design loadings are consistent neither with actual vehicles nor with safety and economy is recognized by many. Bridges are designed for certain hypothetical loadings coupled with low allowable stresses. They serve our present heavy vehicles by virtue of the safety margin provided in the allowable stresses, but both the loads on, and the stresses in, the bridges differ materially from those contemplated in design. Fortunately the bridges are still safe in general; unfortunately their factors of safety are divergent, varying not only for different spans but also for different parts of any one span. To obtain a uniform factor of safety not only must the weight of actual vehicles be used for the design loading but also the expected actual stresses must be taken as the allowable ones.

To secure a uniform factor of safety and simultaneously to take care of special-permit loads, it is proposed that:

1. All present allowable stresses be increased 50 per cent.

2. For all U-loading bridges, live-load stresses should not be calculated for the nominal loading, but instead should be calculated for a loading 60 per cent greater than the nominal design loading (for example, U1280 for U800) when considering lateral and longitudinal forces.

3. All live-load stresses be further calculated for a loading 100 per cent greater than the nominal design loading (for example, U1600 for U800) when not considering lateral and longitudinal forces.

T. Y. Lin—"New Loading Advocated for Highway Bridges"; *Civil Engineering*, April.

GOOD MEDICINE

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Organization for Street Maintenance

Buffalo, N. Y., combines under one engineer the several branches having to do with street pavement maintenance — paving, repairs, laboratory, sidewalks, lateral sewer and water connections, and street repair yard. The Street Paving Branch consists of a civil engineer, 2 senior transitmen, a draftsman, 8 inspectors and 5 engineering aids. The Repairs Branch consists of a clerk, asphalt repair locator and 6 inspectors. The laboratory is in charge of a technician with 2 assistants. In the Sidewalks and Lateral Sewer and Water Connection Branch are a transitman in charge, a clerk, 3 inspectors, paver, cement finisher and 3 laborers, and 3 engineering aids. In the Street Repair Yard are a supervisor, clerk, assistant foreman, paver, 2 curb setters, 18 laborers and 2 watchmen; and the equipment includes two 105-ft. compressors, tractor with broom and plow, 3 concrete mixers, power loader, 12 dump trucks, portable tar kettle, and stone spreader.

The 50 miles of macadam are maintained by city forces. Where cuts are made in a pavement by plumbers, the concrete base is replaced by city employees and the wearing surface by the paving contractor having the street repair contract. Cuts made by gas and electric companies are repaired by them.

Karl S. Masters—"Better Street Maintenance from Good Organization"; PUBLIC WORKS, April.

Paving on The Outer Banks

The Outer Banks of North Carolina is a long chain of islands or sand bars 2,000 to 20,000 ft. wide and rising only a few feet above sea level, lying between the ocean and Pamlico Sound. There are several villages here but no road connecting them, and in 1947 a contract was let for building one 17.3 miles long, and 18 ft. wide. Access to the Banks was difficult, and to confine to the minimum the importing of material and equipment, sand mixed with either portland cement or asphalt seemed logical, and the most economical of these seemed to be a 5" road mix of sand-asphalt. The sand particles are round and not well graded, so that the sand is easily moved by water or wind; for which reason it was decided not to build shoulders and ditches until after completion of the pavement, and to lay this at a level corresponding exactly with the ground contour. The mixture used contained 3.50 gal. of RC-2 asphalt per sq. yd. Mixing of the material was completed in December, but aeration to get the naphtha and water out of the asphalt was postponed until spring, when the pavement was scarified 4" deep, shaped with a grader and rolled with pneumatic rollers. But meantime, while the pavement was still uncompacted, two storms put several miles of it under water and 1,450 ft. of it was washed away. It is believed that this will not happen with the compacted pavement.

W. Vance Baise—"How We Whipped Sand and Water on the Outer Banks Job"; *Roads and Streets*, February.

De-Icing With Rock Salt

Saratoga County, N. Y., has used rock salt for de-icing its 216 miles of roads for two winters past and finds it costs $3.32 per mile treated; while the previous use of treated sand cost $7.59 a mile in 1946-47 when the snowfall was only ⅔ as great. Use of abrasives also necessitated removing them later from pavements and drainage structures. When an ice storm begins, rock salt is spread across the entire width of the highway, at the rate of 400 lb.

When you need special information—consult the READERS' SERVICE DEPT. on pages 93-97

per mile. When snowstorms occur with temperatures of 20° or above, salt is spread as soon as snowing begins, and plowing, beginning when 4" has accumulated, removes it easily in one pass.

F. Ray Williams—"De-Icing Wintertime Pavements With Salt Cuts Maintenance Costs"; *Eng. News-Record*, March 31.

Soil-Cement Roads in Pennsylvania

In building a soil-cement road, the Pennsylvania Highway Dept. cut down the grade and deposited bank-run gravel, leveled it with a grader, spotted cement bags to give a 9% cement content, spread the cement in transverse windrows and leveled it with a broom drag. Then mixing with a cultivator was continued until the mixture had a uniform color. Water was applied and the surface shaped with a blade grader. A weeder removed compaction caused by grader tires, a sheeps-foot roller was used, followed by a weeder and a smooth roller. After a light application of water, a rubber-tire roller was used until a tightly knit surface was obtained. After this base had cured, a bituminous wearing surface was applied. The base cost $1.15 per sq. yd.

"How Pennsylvania Builds Soil-Cement Roads"; *American City*, April.

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Future Trends in Highway Development. By *Bernard E. Gray*, Gen'l Mgr., Asphalt Institute. April, Pp. 4-6.
Hybla Valley Research Project. April, P. 11.

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Prospecting for Gravel Deposits. By *Kenneth F. Bickford*, Geologist, Minnesota Dept. of H'ways. March, Pp. 21-22- 31.
Reducing Maintenance Costs on County and Local Roads. By *J. S. Bright*, Deputy Com'r, P.R.A. March, Pp. 23-26.
Right-of-Way Given for Secondary Routes. By *M. H. Stickler*, R.O.W. Engr., West Va. Road Com'n. March, Pp. 26, 37.
Inventory Your Drainage Structures? (Practices of several highway departments.) March, Pp. 27-28, 35.

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New Loading Advocated for Highway Bridges. By *T. Y. Lin*, Asst. Prof. Civ. Eng., Univ. of California. April, Pp. 43-44.
Adapting Equipment to Special Tools Cuts Cost of Resealing Airport Pavement. By *Wm. R. Wallis*. April, Pp. 42-43.

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De-Icing Wintertime Pavements With Salt Cuts Maintenance Costs. By *F. Ray Williams*, Supt. of H'ways, Saratoga Co., N. Y. March 31, Pp. 52-53.

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Concrete Road Construction: American Practice. By *W. P. Andrews*. March 4, Pp. 137-138.
Air Entrainment of Concrete. By *W. P. Andrews*. March 11, P. 153.
France's Road System. By *M. Georges Linckenheyl*, Pres. Ass'n Tech. de la Route. April 1, Pp. 197-199.

Water and Sewage CHEMISTRY

Information, in simple and understandable terms, on what the water or sewage plant operator needs to help him in his work

MAKING A START IN CHEMISTRY:

SINCE this text is intended primarily for refresher and reference purposes, and for beginners, it is desirable, before starting a discussion of the application of chemicals, to be sure that certain fundamentals are stated so that the meaning of terms, phrases and symbols will be clearly understood.

The Simplest Substances

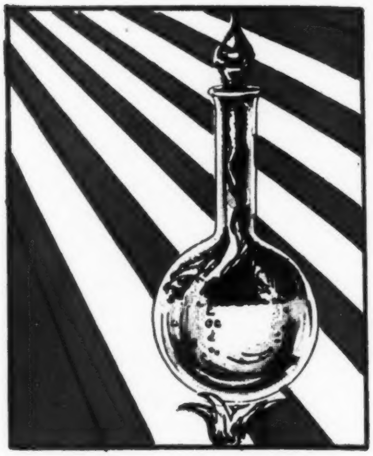
Elements, in chemistry, are those substances which cannot be divided into simpler substances by ordinary chemical changes. Each element is made up of, and consists wholly of, atoms of only one kind. In all, some ninety elements have been discovered, but less than 20 of these have any important application in water, sewerage and similar work; however, a good many others may be used in connection with the various tests and analyses. A list of the chemical elements frequently or occasionally used in water and sewage treatment is shown in Table I. This table also shows the chemical symbols for each (see the next paragraph) and gives their atomic weights (see third paragraph following).

How Chemicals Got Their Names

Most elements have a common or popular name, but in chemical work they are represented by symbols consisting of the first, or the first and another letter of their Latin (or sometimes Greek) names. For instance, Ca is the symbol for calcium; Fe is the symbol for iron, for which the Latin term is ferrum; Ag is used for silver, again based on the Latin term argentum, and Au is similarly used for gold; Pb is for lead or plumbum; N for nitrogen; H for hydrogen; O for oxygen; C for carbon, Cl for chlorine; Cu for copper or cuprum; and Na for sodium.

These symbols are joined together to designate certain chemical compounds. For example, common salt is composed of sodium (Na) and chlorine (Cl) and the symbol or formula for it is NaCl. This indicates that one atom of sodium and one atom of chlorine have combined to form one molecule of salt. Water is a combination of two parts of hydrogen and one part of oxygen, H_2O. The small or subscript "2" indicates that two atoms of hydrogen are combined with one atom of oxygen. Since no subscript appears in the formula for NaCl, it shows that equal numbers of sodium and chlorine atoms are combined. All matter, everything we know of, is composed of combinations of the various elements according to chemical laws. Most matter is made up of simple compounds, composed of only two or three elements; others are very complex. Salt and water, already mentioned, are examples of simple common compounds. On the other hand, the well known insect killer, DDT, or dichloro-diphenyltrichlorethane, is a complicated compound of several elements.

In the operation of modern water and sewage treatment plants, some knowledge of chemistry and chemicals is essential. Whether water is intended for human consumption or industrial use, chemical reactions have a part in its proper treatment. In the disposal of sewage, procedures and controls are based on chemical tests. Our problems of industrial waste disposal and stream pollution abatement can be solved only by combining our chemical and mechanical resources and skills.



". . . controls are based on chemical tests."

How Much Do Atoms Weigh?

Every known chemical element has an atomic weight; however, this atomic weight is relative only and, except for certain gases, cannot be translated into pounds or ounces to indicate how much any specific volume of a chemical actually weighs. The atomic weight of chemicals is based on an assumed atomic weight for Oxygen of 16.00, and represents the true *relative* weights of the other elements. The atomic weight is important, because two or more elements always combine in proportion to the atomic weights of the various elements composing the compound. Thus sodium and chlorine always combine to form sodium chloride in the proportions of 23.00 parts of sodium to 35.46 parts of chlorine.

How We Weigh Chemicals

Some chemicals are solids, some are liquids, others are gases. In any case, each has a specific gravity. In measuring the specific gravity of solids and liquids, they are compared to water which, at a specified

AND CHEMICALS

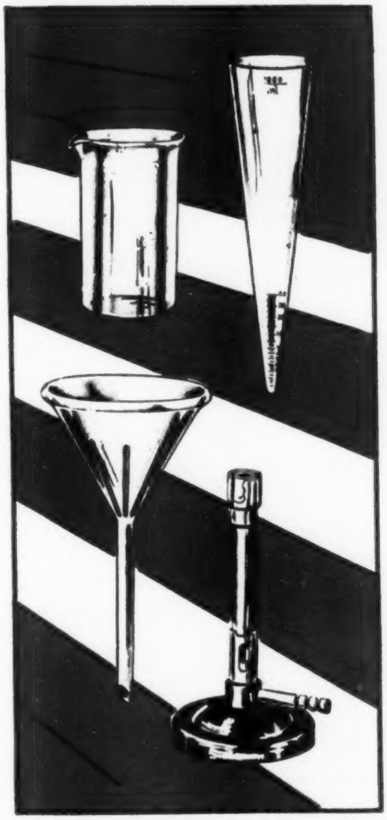
temperature and atmospheric pressure, has a specific gravity of 1.00. A liquid or solid that has, for instance, a specific gravity of 1.85 is 1.85 times as heavy as an equal volume of water. The specific gravity of gases is determined by comparison with the weight of pure, dry air. A gas having a specific gravity of 1.85 weighs 1.85 times as much as an equal volume of air at the same pressure and temperature.

Chemicals also have a certain quality or power of combining with each other. This property is called *valence.* Again, it is a relative power, for the valence of H is assumed as 1, and from this the valence of the other elements is determined, as follows: Since H and Cl combine to form HCl, the valence of Cl is also 1; since two atoms of H unite with one atom of 0 to form H_2O, the valence of O is 2. However, some elements have different valences under different conditions. For instance, CO (carbon monoxide), indicates that C has a valence of 2; but in CO_2 (carbon dioxide), C has a valence of 4. In general, valence is not highly important to the men engaged in water and sewage treatment plant operation, and interested only in the scope of chemical work commonly required for such activities.

Acids, Bases and Salts

These three terms are used frequently, and their meaning must be understood. An acid is a compound that contains hydrogen, which may be replaced by a metal. Thus HCl (hydrochloric acid) may be changed to NaCl (common salt) by replacing the H with Na. In the same fashion, sulfuric acid (H_2SO_4) is changed to calcium sulfate or gypsum ($CaSO_4$) by replacing the H_2 with Ca.

A base is the oxide or hydroxide of a metal. For instance, common bases are CaO (calcium oxide or lime); NaOH (caustic soda or sodium hydroxide); and $Fe(OH)_3$ (ferric hydroxide). Reaction of acids and bases produce salts, for example NaCl, $CaSO_4$ and $CaCO_3$. The latter compound, which is calcium carbonate, is formed when CaO (lime) reacts with carbonic acid (H_2CO_3).



"Chemical analyses must be exact; terms must mean the same to all."

In the above discussion, the term "metal" is not restrictive, and includes potassium, sodium, calcium and magnesium, as well as copper, lead, iron and gold.

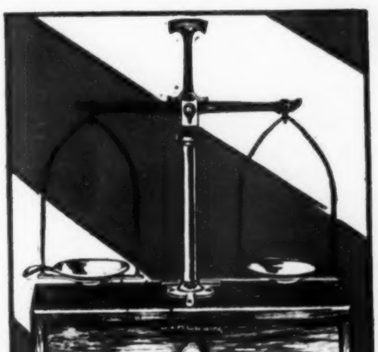
UNITS FOR MEASURING CHEMICALS:

Before proceeding further, it is desirable to consider units of measurement. Chemical analyses must be exact in order to provide necessary bases for chemical reactions, and must be stated in terms that mean the same to everyone. Several methods are in use to indicate the strength of solutions or the amount of a material present in water or sewage. The most common methods are: Parts per million, abbreviated ppm; grains per gallon, abbreviated gpg; pounds per million gallons; and, in the metric system, milligrams per liter, which is equivalent to parts per million.

Our Every-Day Measurements

The U. S.-English System is based on pounds and gallons. In using this system grains should not be confused with the grams of the metric system, as 1 gram equals 15.43 grains. There are 437.5 grains in an ounce, and 16 ounces in the ordinary avoirdupois pound. Therefore, there are 437.5×16, or 7000 grains per pound. Thus 1 grain per gallon equals 1 pound in 7000 gallons, or 142.9 pounds per 1,000,000 gallons ($1{,}000{,}000 \div 7{,}000 = 142.9$). Since 1 gallon of water weighs 8.34 pounds, 1 gpg equals $142.9 \div 8.34$ or 17.1 ppm. Therefore, 1 gpg = 17.1 ppm = 142.9 pounds per million gallons.

Canadian or Imperial gallons are larger than U. S. gallons; the U. S. gallon is 0.83 the Canadian or Imperial gallon. The proportions given



"Many analyses are made by weight instead of by volume."

● ***WELL EQUIPPED laboratory, like the one at Muskegon Heights, Mich., filter plant, has facilities for all phases of plant control.***

above must be modified accordingly.

Example: The hourly flow of water is 55,000 gallons or 0.055 mg. It is necessary to add ½ gpg of lime to the water. How much is required? *Solution:* ½ gpg= 71.4 lbs. per mg. For 55,000 gallons, there will be required 0.055 X 71.4 = 3.93 lbs.

The Metric System Is Simple

In the metric system, the standard unit of volume is the liter (slightly more than one quart). A liter contains 1,000 cubic centimeters (usually abbreviated cc). The term milliliter which means one one-thousandths of a liter (and is abbreviated ml) is now more generally used than cubic centimeter, but for all practical purposes the terms are interchangeable. The standard unit of weight is a gram, which is the weight of one cc (or ml) of water at a standard temperature. The kilogram (kg) is 1,000 grams (about 2.2 pounds); the milligram (mg) is one one-thousandth of a gram. It is convenient to remember that 1 mg per liter equals one part per million.

Hot Or Cold?

Both the Fahrenheit and the Centigrade scales are used to measure temperature. The freezing point of the F scale is at 32°, and of the C scale is at 0°. The F boiling point is 212°, the C is at 100°. The student should become familiar with both of these scales.

There's Still Another Way

The Baume scale is used in the chemical industry. The following are based on the General Chemical Products Book:

In nearly all instances the specific gravity or density in water of solutions of pure chemicals, such as acids, alkalis and salts, varies in proportion to the amount of these constituents present. This fact is used to determine the strength of solutions by obtaining their densities.

The terms density and specific gravity, while strictly not synonymous, are generally interchangeable in representing the weight of a volume of liquid compared with the weight of an equal volume of water. Since the densities of liquids vary with the temperature, the temperature must always be specified. Chemical manufacturers in the United States have agreed on and use 60° F as a basis for specific gravity.

While specific gravity to be accurate must be expressed to four decimal places by figures such as 1.0762, the Baume scale permits the number of decimal figures to be reduced. The relation of the Baume scale to specific gravity is as follows:

For liquids heavier than water:

Degrees Baume =

145 — (145 ÷ Sp. Gr.)

For liquids lighter than water:

Degrees Baume =

(140 ÷ Sp. Gr.) — 130

A Baume hydrometer is used to determine the specific gravity of a solution and results can be obtained to within 0.20° Baume, which in the case of sulfuric acid is equivalent to Sp. Gr. 0.0004 at 66° Baume, or to within 0.11%. This accuracy compares favorably with that obtained by chemical analyses and is satisfactory for most purposes. To obtain this accuracy, reliable, high-grade hydrometers must be used.

Accuracy of all chemical tests depends on careful measurements.

A number of excellent tables of conversion factors are available for easily obtaining metric or other equivalents. Perhaps the most widely used tables for ordinary municipal work are those issued by the Dorr Co. If such tables are needed, write the Editor, who will try to obtain a copy.

CHEMICAL TERMS & WHAT THEY MEAN:

Any compound of any combination of elements will always be in proportion to the atomic weights of the respective elements in the compound. That is, a compound of one atom of iron and one atom of sulfur, always will be in the proportion of 55.85 parts of iron to 32.07 parts of sulfur. In all combinations of chemicals, the

relative weights are in accordance with the atomic weights.

This compound of iron and sulfur is iron sulfide; under proper conditions 55.85 parts of iron and 32.07 parts of sulfur will combine, forming 87.92 parts of the sulfide. If there is an excess of either iron or sulfur, the excess will be unchanged and will not combine. Likewise, in forming common salt, NaCl, there will be 23.00 parts (grams, pounds or tons) of sodium (Na) to 35.46 parts (grams, pounds or tons) of chlorine (Cl). If there are 30 pounds of sodium to 35.46 pounds of chlorine, 7 pounds of the sodium (30-23) will not combine with the chlorine, but will remain intact as sodium.

There are some chemical elements, however, that combine in more than one proportion to form more than one compound. Carbon and oxygen may unite, as previously mentioned, in the proportion of 12.01 to 16.00 to form carbon monoxide (CO), a gas that is poisonous when inhaled; but carbon and oxygen also may unite to form carbon dioxide (CO_2) in which case the proportions are 12.01 parts of carbon to 32.00 parts of oxygen.

These rules apply to all other compounds also. In each case a simple ratio exists between the weight of the elements, and the composition of the compound will be constant and will always be formed when the conditions are the same.

Solution Or Suspension?

When a solid is dissolved in a liquid it forms a solution; gases or liquids may also be dissolved in a liquid in a like fashion to form a solution. Examples of a solid dissolved in a liquid are aluminum sulfate or sodium carbonate dissolved in water; while a water solution of chlorine is an example of a gas dissolved in a liquid.

There are some substances that do not dissolve, as activated carbon. Where the particles of a solid are spread or dispersed through the liquid in a very finely divided state, the mixture is called a suspension. A mixture of Fullers earth and water, such as is used in making turbidity standards, is a suspension.

Solutions are called dilute when they are weak, that is, when they contain only a small amount of dissolved material; or concentrated if very strong; or saturated, at which point the liquid is unable to take up any more of the solid or gas.

For proper use, the strength of solutions must be known, and in laboratory work solutions of a definite, known strength are used in order to make chemical calculations possible. The preparation of such solutions will be discussed later.

The Difference Between Mixtures and Compounds

A mixture of two atoms of hydrogen and one atom of oxygen does not produce water, which has the chemical formula of H_2O; but if a properly proportioned mixture of these two gases is ignited, as by an electric spark, the two gases combine explosively to form water. Hydrogen gas and chlorine gas when mixed together and exposed to sunlight form a compound, HCl, or hydrochloric acid. Copper filings and powdered sulfur mixed together are only a mixture, but when the mixture is heated, it changes its character and becomes copper sulfide.

While outside agencies, as heat or light, are sometimes needed to cause these chemical reactions, this is not always the case. The mere mixing of the substances may result in the formation of the compound.

From the above it will be noted that a compound is a chemical commination of two or more substances, while a mixture is only a mechanical combination; the former cannot be readily resolved into its original parts, while the mixture can.

Ions and Ionization

When acids, bases and salts are dissolved in water the molecules of which they are composed are broken up into positive and negative elements or groups of elements, called radicles (or radicals), each carrying an electrical charge. These charged radicles are called ions. For instance, hydrochloric acid dissolved in water dissociates and the degree to which this dissociation takes place is dependent upon the concentration of the chemical in the water and on the temperature during dissociation. In a normal solution (see this text later for definition of a normal solution) of hydrochloric acid at 18°C, equilibrium is attained with 78% of the HCl dissociated. This can be expressed as:

$$\underset{22\%}{HCl} \rightleftarrows \underset{78\%}{H^{+} + Cl^{-}}$$

This means that in a normal solution of HCl at a temperature of 18°C there is always 22% of the HCl in its original combined form and 78% in the form of positive and negative ions. This condition is not static, but the balance is always maintained unless the temperature or the concentration changes. Increasing the temperature increases the percent of dissociation and vice versa; increasing the concentration decreases the dissociation. Ionization always tends to become more complete as the dilution becomes greater.

Because *only* the ions in a solution enter into a chemical reaction, an acid or a base is known as strong or weak, depending on how much it is ionized in solution. The strong acids, such as hydrochloric, nitric and sulfuric, are highly ionized in solution, as are the strong bases such as sodum hydroxide and potassium hydroxide. Acetic and carbonic acids are but slightly ionized and are therefore known as weak acids.

When two or more acids and bases or salts are dissolved in the same solution, new compounds are formed. If the new compounds are all soluble in water, they intermingle, combine and dissociate and cannot again be separated easily. If, however, one of the compounds is a substance in-

TABLE I—SYMBOLS AND ATOMIC WEIGHTS

Element	*Symbol*	*Atomic Weight*	*Element*	*Symbol*	*Atomic Weight*
Aluminum	Al	26.97	Magnesium	Mg	24.32
Calcium	Ca	40.08	Manganese	Mn	54.93
Carbon	C	12.01	Nitrogen	N	14.01
Chlorine	Cl	35.46	Oxygen	O	16.00
Copper	Cu	63.54	Potassium	K	39.10
Hydrogen	H	1.01	Sodium	Na	23.00
Iron	Fe	55.85	Sulfur	S	32.07

soluble in water (as aluminum hydroxide, commonly called alum floc) it will become chemically inactive and will leave the reaction. For example, when aluminum sulfate, or alum, ($Al_2(SO_4)_3$) is dissolved in water it dissociates into Al^{+++} and SO_4^{--}. If lime is present in the water as $Ca(OH)_2$, it, too, will dissociate into Ca^{++} and OH^-. These ions and salts are in one solution and in contact with each other. Positive ions are attracted to the negative ions and they combine. When the Ca^{++} and the SO_4^{--} ions combine, they form $CaSO_4$ which, being soluble in water, dissociates again and continues in solution. However, when the Al^{+++} ion combines with OH^- ion, aluminum hydroxide is formed which, being insoluble in water does not again dissociate. Thus a floc is started which grows as more molecules of aluminum hydroxide form, until it is the visible floc seen in the coagulation basin. Thus two ions have combined to form a substance which no longer dissociates and which leaves the solution.

What pH Means

The pH of a solution is a measurement of the *intensity* of *acidity*, or its opposite, *alkalinity*. The term "alkalinity" when used in connection with pH should not be confused with the use of the same term to denote the amount of certain dissolved minerals in water. pH is used to designate the degree by which a liquid is acid or anti-acid. pH 7.0 is neutral; figures below 7.0 indicate acidity. For instance pH 6.0 is acid, 5.0 is still more acid; and 4.0 is very acid. Above 7.0, the reverse is true; 8.0 is anti-acid (commonly called alkaline); 9.0 is more strongly anti-acid; and 11.0 very strongly anti-acid. Adding acid lowers the pH; adding alkalies raises the pH.

HOW CHEMICALS COMBINE:

The principles governing the combination of elements to form compounds have already been stated briefly. The atomic and molecular weights are used for determining how much of each element is required to form the desired compound, and also as a check on computations, since both sides of an equation must balance. The procedures explained in connection with the combination of elements to make compounds apply also to the addition of compounds to produce other desired compounds. For instance if quicklime and sulfuric acid are combined, the result will be calcium sulfate and water. The chemical reactions involved are:

$$\mathbf{H_2SO_4 + CaO = CaSO_4 + H_2O}$$

The following form illustrates the method of using atomic weights:

$$\begin{array}{rrl} H_2SO_4: 2H = & 2.02 & \\ S = & 32.07 & \\ 4\,O = & 64.00 & 98.09 \\ CaO: Ca = & 40.08 & \\ O = & 16.00 & 56.08 \end{array}$$

$$\text{Total, } H_2SO_4 + CaO = 154.17$$

$$\begin{array}{rrl} CaSO_4: Ca = & 40.08 & \\ S = & 32.07 & \\ 4\,O = & 64.00 & 136.15 \\ H_2O: 2H = & 2.02 & \\ O = & 16.00 & 18.02 \end{array}$$

$$\text{Total, } CaSO_4 + H_2O = 154.17$$

Thus, the atomic weights on both sides of the equation total 154.17, indicating the equation is correct. Similarly, when sulfuric acid, H_2SO_4, is added to sodium hydroxide, NaOH, producing sodium sulfate, Na_2SO_4, and water, H_2O, it will be

When you need special information—consult the READERS' SERVICE DEPT. on pages 93-97

found that both sides of the equation balance thus:

$$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O$$
$$98.09 + 80.02 = 142.07 + 36.04$$

In making these combinations, all of the elements composing each compound must be properly combined, with none left over. The weight ratio, as shown, is also important in solving various problems in feeding chemicals. For instance, how much sulfuric acid would be required to combine with 100 pounds of CaO, and how much gypsum (calcium sulfate) would be formed?

From the reaction above 98.09 pounds of sulfuric acid are required for combining with 56.08 pounds of CaO. Therefore, 100 pounds of CaO will require $100 \times 98.09 \div 56.08 =$ 175 pounds of sulfuric acid; and this will produce $100 \times 136.15 \div 56.08 =$ 243 pounds of $CaSO_4$; the remainder will be water, as shown previously, amounting to $100 \times 18.02 \div 56.08$, or 32 lbs.

The Water in Chemicals

Some formulas are written thus: $FeSO_4 \cdot 7H_2O$. The $FeSO_4$ indicates ferrous sulfate; the H_2O indicates that the compound is a hydrate, that is, that it contains water; and the 7 indicates the amount of water it contains. Similarly, the true crystal of aluminum sulfate has the formula $Al_2(SO_4)_3 \cdot 18H_2O$ but you can buy aluminum sulfate with either less or more water content. The water content is important in purchasing by weight, and also in computing dosages by weight of crystal. Aluminum sulfate should be purchased on its content of Al_2O_3, and ferric chloride and ferrous sulfate on their iron contents.

What Endings and Beginnings May Mean

As already stated, the force that holds the elements together into compounds is electrical in nature; and since those elements having like electrical charges will not combine, compounds are made up of electro-positive and electro-negative elements. Hydrogen and the metals are positive; and chlorine, oxygen, etc., are negative. When joined in a compound, the name of the compound is formed by the name of the electro-positive element, followed by the name of the electro-negative, with the suffix or ending "ide," as sodium chloride (NaCl); calcium oxide (CaO); and aluminum oxide (Al_2O_3). When two elements form more than one compound, a numerical prefix is used on the electro-negative term, as carbon monoxide (CO); carbon dioxide (CO_2); phosphorous trioxide (P_2O_3); and phosphorous pentoxide (P_2O_5).

When elements form more than one oxide, the suffix "ous" is used to indicate the lower condition of oxidation, and the suffix "ic" to indicate the higher condition. For example, cuprous oxide (Cu_2O) and cupric oxide (CuO). The same suffixes are used in the same way with acids. Sulfurous acid (H_2SO_3) is a combination of sulfur dioxide and water; and similarly sulfuric acid (H_2SO_4) is a combination of sulfur trioxide (SO_3) and water.

The terminations "ite" and "ate" are used to indicate the salts derived from acids terminating in "ous" and "ic," as sodium sulfite (Na_2SO_3); and sodium sulfate (Na_2SO_4).

In some cases there are compounds still lower or higher in the series than those employing "ous" or "ic" endings. The prefix "hypo" is used to distinguish those that are lowest, and the prefix "per" those that are highest. For example, in order of oxygen content, hypochlorous, chlorous, chloric and perchloric acids; and

hypochlorites, chlorites, chlorates and perchlorates.

THE CHEMICALS YOU MAY USE:

As previously stated, only a few chemicals are normally used in water and sewage treatment. These may be grouped under gases, acids, and metals for a brief consideration.

What About the Gases

Chlorine: Symbol Cl, atomic weight 35.46, is 2.49 times as heavy as air. It is a greenish-yellow gas which under pressure is converted to a liquid. Its odor is detectable at a concentration of 3.5 ppm in air; 4.0 ppm is the maximum concentration that can be breathed for one hour without effect; 15 ppm causes throat irritation; 30.1 ppm causes coughing; 40 to 60 ppm is dangerous when inhaled for 30 minutes or more; and 1,000 ppm (one-tenth of one percent) may produce death after 5 minutes exposure.

Oxygen: Symbol O; specific gravity 1.015; atomic weight 16.00: Oxygen is a colorless, odorless gas which combines readily with many elements to form numberless compounds, both organic and inorganic.

Hydrogen: Symbol H; specific gravity 0.07; atomic weight 1.01. Hydrogen is the lightest known material; it is a constituent in all acids, and combines with many other elements.

Hydrogen Sulfide: Symbol H_2S; a colorless gas, heavier than air. The odor in low concentrations is that of rotten eggs. The maximum safe concentration without gas masks is 20 ppm; 700 ppm causes death in a short time; 1000 ppm. causes death almost instantaneously.

Nitrogen: Symbol N; specific gravity 0.97; atomic weight 14.01. Nitrogen is an odorless, colorless and tasteless gas.

Carbon dioxide: Symbol CO_2 molecular weight 44.01; **carbon monoxide,** symbol CO, molecular weight 28.01, an odorless, colorless, poisonous gas.

Ammonia: Symbol NH_3, molecular weight, 17.04.

And the Acids

Hydrochloric or muriatic acid, HCl, when absorbed in water forms hydrochloric acid. The term hydrochloric acid is frequently applied to either the gas or the solution in water, although the correct term for the gas is hydrogen chloride. The standard grade has a specific gravity of 1.178 to 1.188 and a strength of 35% to 37%.

Nitric acid, HNO_3, is a clear, col-

orless or yellow liquid, which is extremely corrosive. It is subject to decomposition by sunlight, turning brown on exposure. Nitric acid, 36° Baume, contains approximately 52.3% HNO_3 but stronger concentrations are available.

Sulfuric acid, H_2SO_4 is a clear or slightly cloudy, heavy liquid with an extremely corrosive action. Specific gravity is from 1.835 to 1.840. The most generally used grade is 66° Baume, which has a strength of 93.2%, but other concentrations are available. The CP (chemically pure) grades are usually 95% to 96% H_2SO_4, the remainder being water, which sulfuric acid takes up readily from the atmosphere. For this reason, solutions may lose strength on standing. When water is added to concentrated sulfuric acid, violent heat is generated; therefore, the acid should always be added to the water carefully in small quantities.

Carbonic acid, H_2CO_3 is a weak acid, used in most charged water and soft drinks. It combines readily with sodium, calcium and magnesium to form carbonates.

And the Metals

Calcium, Ca, atomic weight 40.08, is an alkaline-earth metal. A common compound of calcium is CaO, or quicklime. When water is added, the result is hydrated lime $Ca(OH)_2$. The reaction is:

$$\textbf{lime + water = hydrated lime}$$
$$CaO + H_2O = Ca(OH)_2$$

When carbon dioxide (CO_2) comes in contact with lime, it forms calcium carbonate ($CaCO_3$). When it combines with hydrated lime, it forms $CaCO_3$ and water.

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$$

If still more CO_2 is added, it combines with water to form H_2CO_3, and bicarbonate is formed, as follows:

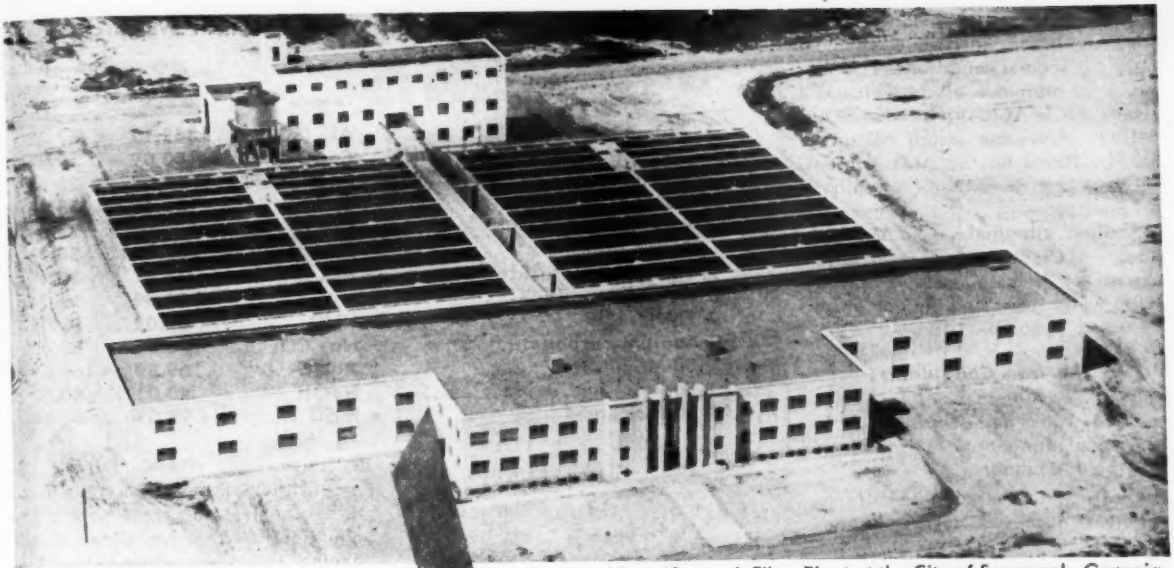
$$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$$

Magnesium, Mg, atomic weight, 24.32, is often found in association with calcium. It enters generally into the same compounds as calcium. Magnesium and calcium are responsible for carbonate hardness in water.

Sodium, Na, atomic weight 23.00, is an alkali metal. Perhaps its principal use in water purification is in sodium carbonate, Na_2CO_3, which is used in the same way lime is used to provide alkalinity or correct corrosiveness or an acid condition in water. Other forms are sodium sulfate (Na_2SO_4), sodium chloride or common salt (NaCl); sodium hydroxide or caustic soda (NaOH); sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) which is used to remove an excess of chlorine following superchlorination; sodium silicate or water glass (Na_2SiO_3 is one of several formulas) is used for coating the inside of water pipes to prevent corrosion; sodium hexametaphosphate, an inhibitor of calcium and other deposits; and calgon which is used to prevent formation of calcium carbonate scale, to control corrosion, and to stabilize dissolved iron.

Potassium, K, atomic weight 39.10, is an alkali metal resembling sodium in many of its characteristics.

Aluminum sulfate, $Al_2(SO_4)_3$. Theoretically the crystal formula is $Al_2(SO_4)_3 \cdot 18H_2O$, but as produced commercially the formula is $Al_2(SO_4)_3 \cdot 14H_2O$. As already stated, the H_2O indicates that the compound is a hydrate (contains water) and the 14 or 18 indicates the amount of water it contains. Aluminum sulfate, commonly called "filter alum," is used for coagulation in both water and sewage treatment. The floc that is formed is aluminum hydroxide. The reactions in coagulation will be explained under "Coagulation."



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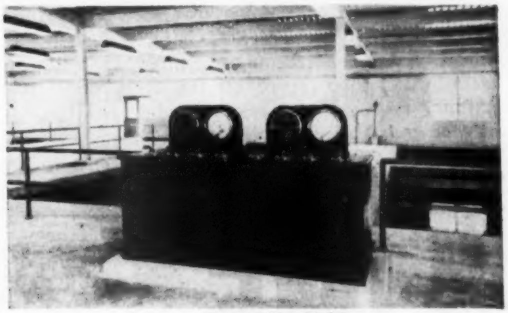

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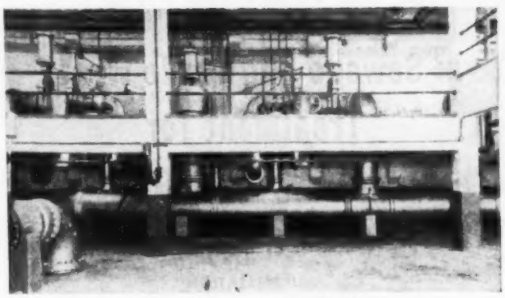
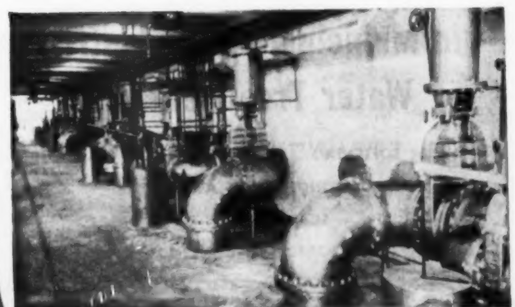


Upper and Lower Pipe Gallery



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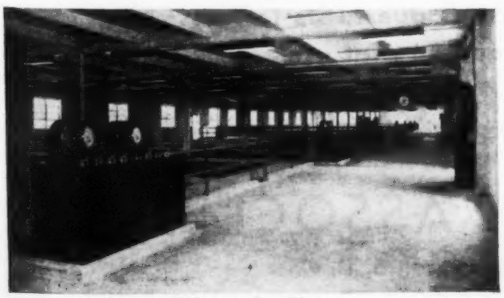

View of Operating Floor

MECHANICAL EQUIPMENT
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Ammonia alum is sometimes used for coagulation, but it is economical only for special conditions. The formula for ammonia alum, which is a true alum, is $Al_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$. Ammonia alum dissolves slowly. Based on the Al_2O_3 content, the cost is greater than for ordinary or filter alum.

Sodium aluminate, ($Na_2Al_2O_4$), is another coagulant that is advantageous for certain uses, primarily with water used for boilers or for steaming purposes.

The Iron Coagulants

Iron, Fe, atomic weight 55.85, is used in water and sewage coagulation in a number of forms, including the following:

$FeSO_4$ .... **ferrous sulfate**
$Fe_2(SO_4)_3$ .... **ferric sulfate**
$FeCl_3$ .... **ferric chloride**

Ferrous sulfate, frequently called copperas, should not be confused with copper sulfate ($CuSO_4$). As commonly purchased, ferrous sulfate has the formula $FeSO_4 \cdot 7H_2O$. When used in coagulation, lime must usually be added to provide the alkalinity necessary for reaction, and oxygen must be available to change the $Fe(OH)_2$ to $Fe(OH)_3$, which is the desired coagulant.

Table 2.—Molecular and Gram-Equivalent Weights

	Compound	Formula	Molecular Weight	Gram-Equivalent Weight
1	Aluminum sulfate	$Al_2(SO_4)_3$	342.12	57.02
2	Calcium carbonate	$CaCO_3$	100.09	50.04
3	Calcium oxide	CaO	56.08	28.04
4	Calcium sulfate	$CaSO_4$	136.15	68.07
5	Ferrous sulfate	$FeSO_4$	151.92	75.96
6	Ferric chloride	$FeCl_3$	162.22	54.07
7	Hydrochloric acid	HCl	36.47	36.47
8	Hydrogen sulfide	H_2S	34.09	17.04
9	Nitric acid	HNO_3	63.02	63.02
10	Sodium carbonate	Na_2CO_3	106.01	53.00
11	Silver nitrate	$AgNO_3$	169.89	169.89
12	Sodium hydroxide	$NaOH$	40.01	40.01
13	Sulfuric acid	H_2SO_4	98.09	49.04

If 3 parts of chlorine are added to 6 parts of $FeSO_4$, 2 parts of ferric sulfate and 2 parts of ferric chloride are produced.

It will be an interesting problem for the student to compute how much chlorine is needed to react with each pound of ferrous sulfate in this solution, remembering that the formula for ferrous sulfate is $FeSO_4 \cdot 7H_2O$ and that an allowance must be made for the weight of the water in the hydrate. He should use the atomic weights previously given and either neglect the right half of the equation or allow for $42H_2O$ in balancing it, this being due to the $7H_2O$ contained in each unit of the $FeSO_4$.

Ferric chloride is available in lump form, the formula being $FeCl_3 \cdot 6H_2O$, and also as a solution. The concentration in solution varies because of the relation between temperature and crystallization, and is about 40%, falling to 35% in cold weather.

Hypochlorites of calcium or so-

dium are used for various purposes, as for sterilizing newly laid mains, chlorinating small water supplies and for similar purposes. The typical formula for calcium hypochlorite is $Ca(ClO)_2$, and for sodium hypochlorite is NaClO.

Activated carbon differs from other chemicals in that its value is measured by what it accomplishes rather than its chemical analysis. The action of activated carbon is by adsorption. When activated carbons adsorb impurities from solution, these impurities are actually removed rather than changed by chemical reaction from one compound to another. The primary application of activated carbon in the water and sewage field is for control of odors.

Other chemicals or compounds employed or encountered in water and sewage work include the following:

NaOH, or sodium hydroxide or caustic soda, used generally as an alkali.

$CuSO_4$, copper sulfate, used in algae control.

NH_3, ammonia used with chlorine for water treatment.

NH_2Cl or $NHCl_2$, chloramine, used in water treatment.

SO_2, sulfur dioxide, used for various purposes in water treatment.

Ozone, O_3, is used in water purification for odor control.

Making a "Standard" Start

A standard solution is one that contains a **known** weight of the substance under consideration in a **definite** volume of solution. Standard solutions are an absolute necessity in making analyses, and such solutions are usually expressed in terms of the **normal** system. To understand fully the normal system, some explanations and a few definitions are necessary.

The **gram-atomic** weight of a substance is the atomic weight of that substance expressed in grams. For example (see Table 1, atomic weights) the atomic weight of sulfur is 32.07, and the gram-atomic weight is 32.07 grams. The atomic weight of sodium is 23.00 and the gram-atomic weight is 23.00 grams.

The **gram-molecular** weight of a substance or compound is the sum of the gram atomic weights of the elements that make it up. For instance, the molecular weight of sulfuric acid, H_2SO_4, is $2.02 + 32.07 + 64.00 = 98.09$, and the gram-molecular weight is 98.09 grams. The gram-molecular weight of sodium carbonate, Na_2CO_3, is $46.00 + 12.01 + 48.00 = 106.01$ grams.

The **gram-equivalent** weight of a compound is computed from these. For acids, the gram-equivalent weight is the gram-molecular weight divided by the number of replaceable hydrogen atoms that they contain. For instance, H_2SO_4 contains two replaceable hydrogen atoms, and the gram equivalent weight is the gram-molecular weight divided by 2; that is, it is $98.09 \div 2 = 49.04$. For bases, the gram-molecular weight is divided by the number of hydrogen or hydroxyl ions entering into the neutralizing reaction. For instance, Na_2CO_3 has the equivalent of two ionizable hydrogen atoms (that is the two Na ions can be replaced by two H ions) and the gram-equivalent weight is therefore $106.01 \div 2 = 53.00$.

The gram-equivalent weights of various compounds are shown in Table 2, page 62.

These gram-equivalent weights are given in most chemistry texts, or they may be computed. Considering aluminum sulfate, the molecular

(Please turn to page 67)

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weight is obtained by adding the atomic weights of the elements that make it up; the number of equivalents ionizable hydrogen atoms can be determined by inspection. For instance we know that SO_4 and 2H combine to form H_2SO_4. Therefore SO_4 will combine with two hydrogen ions. In $Al_2(SO_4)_3$, the Al_2 combines with three SO_4 and therefore it must be equivalent to 6 H ions. Thus the gram equivalent weight is $342.12 \div 6 = 57.02$.

Since Ca can be replaced by H_2 (or 2H), the factor in lines numbered 2, 3 and 4 of Table 2 is 2 and gram equivalent weights are one-half the molecular weights. In line 6, we remember that H and Cl combine, whereas Fe combines with 3Cl; therefore the gram-equivalent weight is the molecular weight divided by 3. In lines 7, 9, 11 and 12 there is only a single H and the molecular and gram equivalent weight are the same.

What "Normal" Means in a Solution

A normal solution contains one gram-equivalent weight of that substance in a liter of solution. A normal solution of sulfuric acid (see Line 13 of Table 2), therefore, contains 49.04 grams of pure sulfuric acid in one liter of solution; usually the pure acid is added to distilled water to make up the required quantity of one liter. Likewise a normal solution of calcium carbonate contains 50.04 grams (see Line 2 of Table 2) of the pure calcium carbonate in one liter of solution. A milliliter (or a liter, quart, etc.) of the sulfuric acid solution will exactly neutralize a milliter (or liter, quart, etc.) of the calcium carbonate solution.

An 0.02N, a fiftieth normal or an N/50 solution of sulfuric acid are all the same and will contain 1/50 of 49.04 grams or 0.98 gram of pure sulfuric acid in 1 liter. In the case of calcium carbonate, one liter of an N/50 solution will contain $50.04 \div 50$ or almost exactly 1.00 gram of pure calcium carbonate.

A tenth normal (0.10 or N/10) solution of sulfuric acid will contain 4.904 grams of pure acid in a liter of solution; a normal solution, as already stated, will contain 49.04 grams; a 10N solution will contain 490.4 grams, etc.

The preparation of these normal solutions must begin with some material that can be obtained in a pure state; sodium carbonate is usually employed initially. A solution of normal or less than normal strength is obtained by weighing out the required amount, and this is diluted as desired. From this standard solution, sulfuric acid and other solutions are made up by checking against the original. The procedure requires some practice and skill in handling chemicals and chemical equipment. A particularly clear description of the detail procedure to be followed is given in Theroux, Eldridge & Mallman's book. It is better for the small sewage or water plant laboratory without a trained chemist to purchase solutions of definite strength already made up, or ampoules containing these solutions ready for use.

Solutions may change in strength as time passes, and they should be checked by titrating them against solutions of known strength, and their variation from normal determined and corrected for in subsequent calculations. Titration means adding measured small quantities of the standard until a definite endpoint is shown. In actual laboratory practice, solutions are not always kept at exact normal strength, but

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their actual strength is known and proper allowances made in the computations.

"Molar" Solutions in Chemistry

A molar solution of a substance is a solution that contains one gram-molecular weight of the substance in one liter of solution. As already stated, the gram-molecular weight is the sum of the gram-atomic weights of the elements that make up the compound. Molar solutions are indicated by strength in the same way that normal solutions are indicated; that is, 0.01M or M/100; M/50; 10M. etc.

A molar solution of sulfuric acid contains 98..09 grams of the pure acid in one liter; an 0.02M solution (M/50 solution) contains 1.9618 grams; and an 0.01M (M/100 solution contains 0.98 gram, or exactly the same as an N/50 solution. In the case of H_2SO_4, Na_2CO_3 and other compounds that have two replaceable hydrogen atoms, the Molar solution is twice as strong as the Normal solution, and an M solution equals a 2N solution. In the case of those compounds that have but one replaceable hydrogen atom, as HNO_3, HCl and NaOH, the gram equivalent weight is the same as the gram molecular weight, and the Molar and Normal solutions are of equal strength.

Making Chemical Tests

It is not the purpose of this text to explain the procedure in making chemical tests, for which "Standard Methods" or the excellent text by Theroux, Eldridge and Mallman should be followed, but it is desirable to be familiar with the various terms used in connection with them. General methods employed in testing include qualitative analyses, which are made to determine what elements or compounds are present; and quantitative analyses which are made to determine the amounts present.

Before attempting to determine the amount of chemical compounds present, it is necessary to determine the kinds of compounds that are in the sample. In many cases, a qualitative analysis is all that is necessary, but in other cases it will serve as a guide to the methods to be employed for further testing. A very simple form of qualitative analysis is the addition of orthotolidine solution to water to determine if chlorine is present. The presence of color indicates that chlorine is present; and, as a matter of fact, this test is quantitative also, since the intensity of color indicates the amount of chlorine in the water; and the method of anlaysis is colorimetric.

Gravimetric quantitative analyses are made by weighing the amount of compound that is present in the sample, the compound first being changed by appropriate methods so that it is insoluble and easily separated. For example, the determination of sulfur in a sample of sewage involves changing the sulfur to sulfate and combining it with a soluble salt of lead or barium. The resulting compound is insoluble and can be removed by filtration and weighed, permitting the amount of sulfur in the original sample to be calculated.

Volumetric quantitative analyses are made by adding a chemical of known concentration or strength to an exact quantity of the sample. The volume of the reagent required for the desired reaction permits the amount of chemical in the sample to be calculated. For example, the alkalinity of water is determined

by adding to a sample of 100 ml. (after phenolphthalein or methyl orange indicator has been added) N/50 sulfuric acid until a color change is noted. The alkalinity of the water, expressed in parts per million, is 10 times the number of milliliters of N/50 sulfuric acid required to produce the color change.

Colorimetric quantitative analyses involve the determination of the amount of unknown chemical in the sample by matching the color produced by adding the same chemical to a set of samples containing a known amount of the chemical being tested for, or by artificial color standards. This method is valuable in determining the presence and amounts of minute quantities of chemicals. For example, nitrites in water or sewage can be determined by adding a chemical that produces a distinct color in the sample; and matching this color with that produced by adding the same chemical to previously prepared tubes containing known amounts of nitrites.

Turbidimetric analyses are used in determining the amount of turbidity present in a sample by matching it with a series of suspensions of known turbidity. This is illustrated in the use of the familiar turbidity samples.

CHEMISTRY IN WATER TREATMENT

In water treatment, chemistry is used in the determination of alkalinity, in softening, in coagulation, in corrosion control and in various fields of water treatment.

What About Alkalinity, Hardness and Salinity?

Alkalinity, salinity and hardness are caused by the presence of certain chemical compounds in the water. A determination of the kinds and amounts of these may be necessary for proper treatment procedures. Compounds that cause alkalinity, hardness and salinity may be grouped as follows:

Those that cause alkalinity only:
Potassium carbonate, K_2CO_3
Potassium bicarbonate, $KHCO_3$
Sodium carbonate, Na_2CO_3
Sodium bicarbonate, $NaHCO_3$

Those that cause both alkalinity and carbonate hardness:

Calcium carbonate, $CaCO_3$
Calcium bicarbonate, $Ca(HCO_3)_2$
Magnesium carbonate, $MgCO_3$
Magnesium bicarbonate, $Mg(HCO_3)_2$

It will be noted that the potassium and sodium compounds do not cause hardness, but that all carbonates and bicarbonates cause alkalinity, while all calcium and magnesium compounds cause hardness, whether in the carbonate, bicarbonate, sulfate or chloride form.

Those that cause both salinity and non-carbonate hardness:

Calcium sulfate, $CaSO_4$
Calcium chloride, $CaCl_2$
Magnesium sulfate, $MgSo_4$
Magnesium chloride, $MgCl_2$

Other salts that cause salinity, but not hardness:
Potassium sulfate, K_2SO_4
Potassium chloride, KCl
Potassium nitrate, KNO_3
Sodium sulfate, Na_2SO_4
Sodium chloride, NaCl
Sodium nitrate, $NaNO_3$

Caustic alkalinity occurs when there is an excess of lime in the water and this excess may precipitate in the distribution system or on the sand of a filter bed as $CaCO_3$. Caustic alkalinity does not occur naturally.

Acidity in water is caused by free CO_2, by mineral acids, by iron or aluminum sulfates and by some other less common compounds.

Basic Tests for Alkalinity

The basic tests for alkalinity are those for phenolphthalein alkalinity and for methyl orange alkalinity. The method of performing these tests will not be described here as there are a number of excellent texts available describing the procedures in detail.

The phenolphthalein and methyl orange alkalinity determinations show the kinds of alkalinity that are present in the water. Phenolphthalein measures none of the bicarbonates, half of the normal carbonate and all of the hydroxide alkalinity; and methyl orange measures the total of all alkalinity. All alkalinity is measured in terms of $CaCO_3$. The relationships between these three kinds of alkalinity are shown in the following examples:

(1) If the alkalinity to phenolphthalein is 0, that is, there is no color reaction to the addition of the phenolphthalein indicator solution, there is no caustic alkalinity and no carbonate alkalinity, but the alkalinity to methyl orange as shown by the test represents the bicarbonate alkalinity.

Example: Alkalinity to phenolphthalein is 0.0 ppm; and to methyl orange is 18.5 ppm. Caustic alkalinity is 0; carbonate alkalinity is 0; and bicarbonate alkalinity is 18.5 ppm.

(2) When the alkalinity to phenolphthalein is less than one-half the alkalinity to methyl orange, there is no caustic alkalinity; the carbonate alkalinity is twice the phenolphthalein alkalinity; and the bicarbonate alkalinity is the methyl orange alkalinity minus twice the phenolphthalein alkalinity.

Example: Alkalinity to phenolpthalein is 28.0 ppm; and to methyl orange 86.0 ppm. Caustic alkalinity is 0; carbonate alkalinity is 56.0 ppm. and bicarbonate alkalinity is 86 — (2 x 28) = 30 ppm.

(3) When the phenolphthalein alkalinity is exactly one-half of the methyl orange alkalinity, the caustic alkalinity is 0, the carbonate alkalinity is the same as the methyl orange alkalinity, and the bicarbonate alkalinity is 0.

Example: Phenolphthalein alkalinity is 72.0 ppm and methyl orange alkalinity is 144.0 ppm. The caustic alkalinity is 0.0 ppm.; the carbonate alkalinity is 144.0 ppm; and the bicarbonate alkalinity is 0.0 ppm.

(4) When the phenolphthalein alkalinity is more than one-half of the methyl orange alkalinity, caustic alkalinity is twice the phenolphthalein alkalinity minus the methyl orange alkalinity; the carbonate alkalinity is twice the difference between the methyl orange and phenolphthalein alkalinities; and the bicarbonate alkalinity is 0.

Example: The phenolphthalein alkalinity is 150 ppm; the methyl orange alkalinity is 196 ppm. The caustic alkalinity is 2 x 150 — 196 = 104 ppm.; the carbonate alkalinity is 2 x (196 — 150) = 92 ppm; bicarbonate alkalinity is 0.

(5) When the phenolphthalein and methyl orange alkalinities are the same, all the alkalinity is caustic alkalinity and carbonate and bicarbonate alkalinities are 0.

Example: Phenolphthalein alkalinity is 120; alkalinity to methyl orange is 120. Hydroxide alkalinity is 120, and carbonate and bicarbonate alkalinities are 0.

The utility and method of use of alkalinity determinations will be indicated in material presented hereafter.

The Two Kinds of Hardness

Hardness is of two kinds, carbonate hardness, sometimes called temporary hardness because part if it is removable by boiling; and non-carbonate hardness, also called permanent hardness because it is not affected by boiling. Carbonate hardness, as already stated, is due to calcium and magnesium carbonates and bicarbonates; the calcium carbonate is insoluble except for a residual of between one and two grains per gallon, so that partial softening is obtained by changing these bicarbonates to carbonates. Non-carbonate hardness is caused by calcium and magnesium sulfates and chlorides, also as previously stated.

CHEMISTRY AND WATER SOFTENING

There are two principal methods of water softening—the lime or lime-soda process and the use of zeolites. These will be discussed separately and only from the viewpoint of the elementary chemical procedures involved. As a basis for lime-soda softening, certain tests are necessary.

Determining the Hardness

A test for total hardness is necessary to measure the amount of calcium and magnesium compounds, which include those causing carbonate as well as non-carbonate hardness. That is, total hardness tests will show the amounts of the compounds causing hardness.

The test for hardness, with the analyses for phenolphthalein and methyl orange alkalinity, permit the computation of many other factors showing information on the characteristics of the water.

When total hardness and alkalinity are the same, calcium and magnesium bicarbonates and carbonates produce all of the hardness, which is carbonate hardness. **Example:** Alkalinity to methyl orange 60; total hardness 60. All hardness is due to calcium and magnesium carbonates and bicarbonates.

When total hardness exceeds alkalinity, the hardness is made up of the carbonate hardness, which equals the alkalinity, and the non-carbonate hardness which equals the total hardness less the alkalinity. **Example:** Total hardness 80; alkalinity 60; non-carbonate hardness is $80 - 60 = 20$; carbonate hardness is 60.

When the total hardness is less than the alkalinity, there is no non-carbonate hardness, and the difference between the total hardness and alkalinity measures the amount of sodium and potassium carbonates that are present. **Example:** Total hardness 60; alkalinity 80. All of the hardness is carbonate hardness; and there are $80 - 60 = 20$ parts of sodium and potassium carbonates and bicarbonates.

In water softening, these sodium and potassium carbonates and bicarbonates can be neglected, as they do not affect hardness. In analyses, these are stated as negative non-carbonate hardness and are subtracted from the alkalinity to show total hardness.

How Chemicals Soften Water

As already stated, the carbonate hardness is due to the presence of calcium and magnesium bicarbonates and carbonates, but the calcium carbonate is only slightly soluble in water—to the extent of about 20 to 30 ppm. In excess of this amount, the carbonates are insoluble and will precipitate or settle out. Therefore, by changing the bicarbonates to carbonates, carbonate hardness can be reduced to about 30 ppm.

This can be accomplished by adding lime which combines with the CO_2 in the bicarbonates and converts them to normal carbonates. The reaction for calcium bicarbonates when hydrated lime is added is: $Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$.

The reaction with magnesium is the same, but since $MgCO_3$ is soluble, it is converted to $Mg(OH)_2$ by the addition of more lime. This addition of an excess of lime produces caustic alkalinity; and when magnesium is present forms magnesium hydroxide, which precipitates in large white flakes. The reaction is:

$MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$.

The non-carbonate hardness ($CaSO_4$) can be removed by adding soda ash (Na_2CO_3), as follows: $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$.

When using lime, consideration must be given to the CaO content. The atomic weight of Ca is 40.08 and of O is 16, and the total molecular weight of CaO is therefore 56.08. Hydrated lime consists of CaO and H_2O, and is therefore $Ca(OH)_2$; the molecular weight is $40.08 + 2.02 + 32.00$, or 74.10. On the basis of effective CaO, therefore, hydrated lime is by weight equal to $56.08 \div 74.10 = 75.7\%$ of CaO. However, purchased lime may contain only 90% to 95% of CaO. These impurities, if present, must be determined and allowed for.

Softening Computations

In lime softening computations, analyses are required to show the free CO_2, the half-bound CO_2, the non-carbonate hardness and the total magnesium. Lime must be added to react with all of these. Half-bound CO_2 equals 44% of the alkalinity, as follows: The atomic weight of $CaCO_3$ is 100.09, and of CO_2 is 44.01, which is 44% of the weight of $CaCO_3$.

The amount of lime theoretically required to react with CO_2 is determined by adding together the free CO_2 and the half-bound CO_2, both expressed in parts per million and multiplying by a factor which is determined as follows: The atomic weight of $CaCO_3$, which is the compound into which it is desired to convert the CO_2 by the addition of lime, is $40.08 + 12.01 + 48.00 = 100.09$, of which the weight of CO_2 is 44.01, and of CaO is 56.08. For each part per million of CO_2 present, there will be required $56.08 \div 44.01 = 1.272$ parts of CaO. Since 1 ppm equals 8.34 pounds per million gallons, $8.34 \times 1.272 = 10.6$ pounds of lime for each part per million of CO_2, whether free or half-bound, per million gallons of water. (These data are for lime with 100% CaO and must be corrected for the actual CaO content of the lime used).

Soda ash is required to remove non-carbonate hardness, which it does by converting the calcium sulfates and chlorides to calcium car-

bonates and sodium sulfates and chlorides. Since the non-carbonate hardness is expressed by the tests as parts per million of $CaCO_3$, for each ppm of non-carbonate hardness, there will be required 46.00 + 12.01 + 48.00 = 106.01 (the atomic weight of Na_2CO_3) divided by 100.09 (the atomic weight of $CaCO_3$), or 106.01 ÷ 100.09 x 8.34 = 8.84 pounds of soda ash per million gallons for each part per million of non-carbonate hardness.

The removal of magnesium is accomplished by adding lime. The analysis should show the total magnesium present. This magnesium, which is in the form of chlorides, carbonates or sulfates, must be changed by the addition of lime to magnesium hydroxide ($Mg(OH)_2$). The reactions may be: $MgCl_2 + Ca(OH)_2 = CaCl_2 + Mg(OH)_2$; $MgCO_3 + Ca(OH)_2 = CaCO_3 + Mg(OH)_2$; or $MgSO_4 + Ca(OH)_2 = CaSO_4 + Mg(OH)_2$.

The $Ca(OH)_2$ is, of course, hydrated lime, that is $CaO + H_2O$, but computations are on the basis of CaO.

Since the analyses show the magnesium present in any of the above forms, the amount of lime required is as the atomic weight of CaO and Mg, or 56.08 and 24.32; and for each ppm of Mg there will be required 56.08 ÷ 24.32 = 2.306 ppm of lime, or 2.306 x 8.34 = 19.23 pounds per million gallons. If there are 20 ppm of total magnesium, 20 x 19.23 = 384.6 pounds of lime will be required per million gallons.

Examples of Calculations

Example: The analyses of a water shows the following: Free CO_2, 2 ppm; alkalinity 60 ppm; non-carbonate hardness 55 ppm; total magnesium 12 ppm. To determine the amount of chemicals required for treatment:

The first decision to be made is the amount of hardness to be removed. It is not generally desirable to remove all of the hardness; assuming that it is desired to remove all but 35 ppm of non-carbonate hardness, non-carbonate hardness to be removed is 55 — 35 = 20 ppm.

Lime will be used as follows: To neutralize CO_2, free and half-bound, 2 + (60 x .44) = 28.4 ppm. Then 28.4 x 10.6 = 301 pounds per million gallons. To react with and remove the magnesium, 12 x 19.23 = 231 pounds per million gallons. Total lime required per million gallons = 301 + 231 = 532.

Soda ash required for removal of non-carbonate hardness, amounts to 20 x 8.84 = 176.8 pounds per million gallons.

If alum is used for coagulant, additional soda ash or lime may be required, as shown later.

The above computations are on the basis of 100% CaO lime and 100% Na_2CO_3. Corrections must be made for lower purities or contents.

The $CaCO_3$ resulting from the addition of lime settles best at pH 9.4, whereas the $Mg(OH)_2$ settles best at pH 10.6. For most effective removal of hardness, therefore enough lime may be added to produce the magnesium floc at pH 10.6. After settling, CO_2 can be added by a recarbonation process to reduce the pH to 9.4 at which point the calcium carbonate settles best. In order to deliver a water that will not deposit $CaCO_3$, further recarbonation is utilized to reduce the pH to 8.7 or lower or Calgon may be employed to stabilize the water with respect to calcium carbonate.

The results obtained by these computations are subject, in actual practice, to variations and the theoretical computed dosage may not

be exactly that actually needed. It is always desirable to check the calculated amounts of chemicals by means of jar tests, using a liter, a quart or a gallon of water and noting results.

How Zeolites Soften Water

Zeolites are hydrous silicates of sodium and aluminum, which have the ability of absorbing calcium and magnesium (the hardness-causing elements) from water while releasing or exchanging an equal amount of sodium. The softening reaction, using Z for the zeolite compound is: sodium zeolite + calcium bicarbonate = calcium zeolite + sodium bicarbonate, or $Na_2Z + Ca(HCO_3)_2 = CaZ + 2\ Na(HCO_3)$.

The same reaction occurs with magnesium. These materials are drawn from the water and sodium bicarbonate is returned. When the capacity of the zeolite to take up calcium and magnesium is exhausted, a strong salt solution is passed through the zeolite, which then exchanges the absorbed calcium and magnesium for the sodium. After this process has been completed, the zeolite will again absorb practically the original quantity of calcium and magnesium. The reaction with the brine is:

$$CaZ + 2NaCl = Na_2Z + CaCl_2$$

Carbonaceous zeolites remove sodium, magnesium and calcium, replacing these with hydrogen. In conjunction with ordinary zeolites, the carbonaceous zeolites control the alkalinity of the water. Reactions are, using Z for the zeolite:

$$Ca(HCO_3)_2 + H_2Z = CaZ + 2H_2CO_3$$
$$Mg(HCO_3)_2 + H_2Z = MgZ + 2H_2CO_3$$
$$Na_2(HCO_3)_2 + H_2Z = Na_2Z + 2H_2CO_3$$
$$CaSO_4 + H_2Z = CaZ + H_2SO_4$$
$$MgSO_4 + H_2Z = MgZ + H_2SO_4$$
$$Na_2SO_4 + H_2Z = Na_2Z + H_2SO_4$$

The zeolite is regenerated by sulfuric acid as follows:

$$\left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\} Z + H_2SO_4 = H_2Z + \left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\} SO_4$$

Using Aluminum Sulfate for Coagulation

When aluminum sulfate, $Al_2(SO_4)_3$ is used as a coagulant, alkalinity must be available to form the desired floc. When calcium bicarbonate, $Ca(HCO)_2$ is used to supply the alkalinity, it combines as follows:

$$Al_2(SO_4)_3 + 3\ Ca(HCO_3)_2$$

and the following compounds are produced:

$$3\ CaSO_4 + 2\ Al(OH)_3 + 6\ CO_2.$$

It will be noted that three Ca units are necessary to combine with the three (SO_4) units; and that the six HCO_3 units break down into six CO_2 and two $(OH)_3$ units. In the 3 $Ca(HCO_3)_2$, there are six H, six C and eighteen O. In the six CO_2 units there are six C and twelve O; in the $(OH)_3$ units there are six O and six H. Thus the equations balance.

Theoretically, for complete reaction, 7.7 ppm of alkalinity are required for each grain per gallon of aluminum sulfate. This theoretical figure is based on using calcium carbonate for supplying the alkalinity. If 3 $CaCO_3$ is substituted in the above equation for 3 $Ca(HCO_3)_2$, by atomic weights, remembering that aluminum sulfate has a theoretical formula of $Al_2(SO_4)_3 \cdot 18H_2O$, atomic weights are:

	Al,	26.97 x 2	= 53.94
	SO_4	96.07 x 3	= 288.21
	H_2O,	18.01 x 18	= 324.18
Total	$Al_2(SO_4)_3.18H_2O$		= 666.33
	Ca,	40.08 x 3	= 120.24
	C,	12.01 x 3	= 36.03
	O_3,	48 x 3	= 144.00
Total	$CaCO_3$		= 300.27

The relation of 666.33 to 300.27 indicates that 300.27 ÷ 666.33, or 45% as much $CaCO_3$ will be required as $Al_2(SO_4)_3$. The equivalent of 1 gpg is 17.1 ppm, and 45% of 17.1 ppm is 7.7 ppm. This is the theoretical alkalinity required; actually, the amount may vary from 6 to 10 ppm. When lime (CaO), hydrated lime [$Ca(OH_2)$], or soda ash (Na_2CO_3) is used, computations should be made as above. Also, allowance should be made to permit an excess alkalinity of 20 to 25 ppm in the treated water to prevent corrosion. Step-by-step procedures for determining alkalinity requirements, and computing chemical dosages were published in this magazine in the April, 1948, issue under the title "Operation of Water Treatment Plants." These procedures covered (a) preparation of solutions, (b) establishing dosages of coagulants for alkaline waters and for waters deficient in alkalinity, and (c) the prevention of corrosion.

Using Iron Salts for Coagulation

Ferric sulfate has the formula $Fe_2(SO_4)_3 \cdot 9H_2O$. Alkalinity is required for the coagulation reaction, and if the water or sewage does not contain enough alkalinity, it must be supplied by lime or soda ash. When hydrated lime is added to ferric sulfate: $Fe_2(SO_4)_3 \cdot 9H_2O + 3\ Ca(OH)_2$, there

are produced: 3 $CaSO_4$ + 2 $Fe(OH)_3$.

In practice, the alkalinity of the water should be determined by appropriate tests, and any deficiency supplied by adding lime or soda ash. To determine the amount of lime to be added, proceed as follows with atomic weights:

H_2O,	18.02 x 9 =	162.18
Fe,	55.85 x 2 =	111.70
SO_4	96.07 x 3 =	288.21
Total $Fe_2(SO_4)_3 \cdot 9H_2O$ =		562.09
Ca,	40.08 x 3 =	120.24
$(OH)_2$,	34.02 x 3 =	102.06
Total $Ca(OH)_2$		222.30

If there is no alkalinity in the water, 222.3 pounds of hydrated lime will be required for each 562.09 pounds of ferric sulfate of the formula $Fe_2(SO_4)_3 \cdot 9H_2O$. If the amount of ferric sulfate applied is 1 gpg, or 142.9 pounds per million gallons, the amount of hydrated lime required will be 222.3 x (142.9 ÷ 562.09) = 56.5 pounds of 100% hydrated lime. If the lime is 95% pure, about 60 pounds will be required.

It is perhaps more often the case that some alkalinity is present in the water, but not enough for the reaction to take place. Assuming that there are 5 ppm. of natural alkalinity as $CaCO_3$ in the water, the reaction with ferric sulfate will be incomplete.

For reaction, the ferric sulfate will require 3 x (40.08 + 12.01 + 48.00) = 300.27 pounds of calcium carbonate for each 562.09 pounds of ferric sulfate. For a dosage of 1 gpg, there will be required 300.27 (142.9 ÷ 562.09) = 76.2 pounds per million gallons. If there are 5 ppm of natural alkalinity available in the water, this amounts to 5 x 8.34 = 41.7 pounds, and only 76.2 — 41.7 = 34.5 pounds per million gallons of alkalinity must be added. The relation, by atomic weights, between calcium carbonate and hydrated lime is 100.09:74.01, and there will be required 34.5 ÷ .74 = 46.6 pounds of hydrated lime per million gallons. In practice, as already stated, some excess alkalinity is desirable; also many factors, as temperature, mixing, etc., affect the reaction; and computations cannot be made as closely as the theoretical problem given. Probably a residual alkalinity of 20 to 25 ppm. would be desirable and the dosage of lime would be increased accordingly.

Ferric chloride, $FeCl_3$, is also used for coagulation. When hydrated lime is added to supply alkalinity, 2 $FeCl_3$ + 3 $Ca(OH)_2$, there are produced ferric hydroxide and calcium chloride, 2 $Fe(OH)_3$ + 3 $CaCl_2$. If calcium bicarbonate is present, the reaction is the same, except that CO_2 is also produced.

The atomic weights of the iron and of the hydrated lime are, remembering that ferric chloride contains 6 atoms of water of crystallization, in the relation of 540.70 to 222.30. Therefore, 222.3 pounds of hydrated lime will be required to react with 540.70 pounds of ferric chloride, and the amount of lime required can easily be computed for any dosage of ferric chloride. In computing the requirements for natural alkalinity, which is based on $CaCO_3$, the same procedure as for ferric sulfate is employed.

Removing Iron and Manganese

Iron and manganese are usually quite closely associated in water supplies and if one is present, the other is quite likely to be also. Iron is usually present as either ferrous bicarbonate, $Fe(HCO_3)_2$, which is soluble; or as ferrous hydroxide, $Fe(OH)$. If oxygen is added to either of these,

rust or ferric hydroxide, $Fe_2(OH)_6$ is formed which is insoluble. Therefore these iron compounds can be removed by oxidation, since the $Fe_2(OH)_6$ forming in water will settle out.

Manganese is more difficult than iron to remove. Manganese compounds usually found in water are manganese hydroxide, $Mn(OH)_2$, which is insoluble; or manganese dioxide, MnO_2. The reactions are not the same as with iron, and if much manganese is associated with the iron, it may interfere with iron removal. Manganese can be removed by break-point chlorination at pH values of 9.4 and above.

Instead of removing the iron and manganese from the water, they may be stabilized so that they will not precipitate in the distribution system and cause complaints of red or black water. Several commercial compounds, as calgon, are available for this purpose. To be successful, a definite ratio of the chemical to the iron or manganese must be employed, and the chemical must be introduced before the water is exposed to air or is treated with chlorine. Either air or chlorine oxidizes the iron or manganese, forming insoluble compounds which settle.

Scale and Corrosion Prevention

Corrosion is due to the solution of exposed metal by water; its rate is inversely proportional to the alkalinity and the pH and directly proportional to the content of dissolved oxygen, carbon dioxide, temperature and time of contact. A method preventing corrosion is to adjust the pH value, the CO_2 content and the alkalinity so as to deposit and maintain a thin coating of calcium carbonate on the interior of the piping system.

The first step in corrosion control is to determine the Co_2 content (see Standard Methods) and the alkalinity to methyl orange. Assuming a water with a CO_2 content of 10 ppm. and a methyl orange alkalinity of 80 ppm., the general procedure given for softening is followed: The free CO_2 is 10 ppm.; the half-bound CO_2 is 44% of the alkalinity, or 44% of 80 ppm., or 35.2 ppm. Total CO_2 to be neutralized is $35.2 + 10 = 45.2$ ppm. The atomic weight of $CaCO_3$, which is the compound that will be formed when CaO is added to CO_2, is 100.09, of which the weight of CO_2 is 44.01 and of CaO is 56.08. For each ppm of CO_2, there will be required $56.08 \div 44.01 = 1.272$ ppm of CaO. Since 1 ppm equals 8.34 pounds per million gallons, there will be required, for

each ppm of CO_2, 8.34 x 1.272 = 10.6 pounds of lime per million gallons. For the 45.2 ppm CO_2 computed above, there will be required 45.2 x 10.6 = 479.1 pounds of lime per mg. If phenolphthalein alkalinity is also present, compute bicarbonate alkalinity as indicated under alkalinity.

By means of a jar test (see PUBLIC WORKS, April 1948) the amount of lime necessary to prevent corrosion can be determined.

A full discussion of the problems and methods of corrosion prevention appeared in the April, 1949, issue of PUBLIC WORKS.

Expressing Chemical Results

In much of the work covered by this text, the weights or amounts, of the various substances are given in parts per million, which for the purpose of the text have been abbreviated to ppm. Some of these weights or amounts are very small. A standard has been adopted for reporting results, as follows: Except for certain nitrogen compounds, two decimal places are used for ppm between 0.1 and 1.0, as 0.32; for values between 1 and 10, one decimal place is used, as 4.1; between 10 and 100, the nearest whole number is used, as 29; and over 100, only two significant numbers are used, as 180, not 183. When results are tabulated, ciphers should not be added to have the same number of decimal places in each.

Subsurface Sewage Disposal

(Continued from page 29)

policy is . . ."if conditions are such as to indicate the need for more than 3,000 ft. of drain tile, some other form of secondary treatment will be required." This is good policy anywhere.

When two siphons are used, each should serve one-half of the field and should dose alternately. Size of the dosing tank should be such that discharge does not occur more frequently than once in 3 or 4 hours. The tank capacity should not exceed 70% to 80% of the interior capacity of the tile line to be dosed.

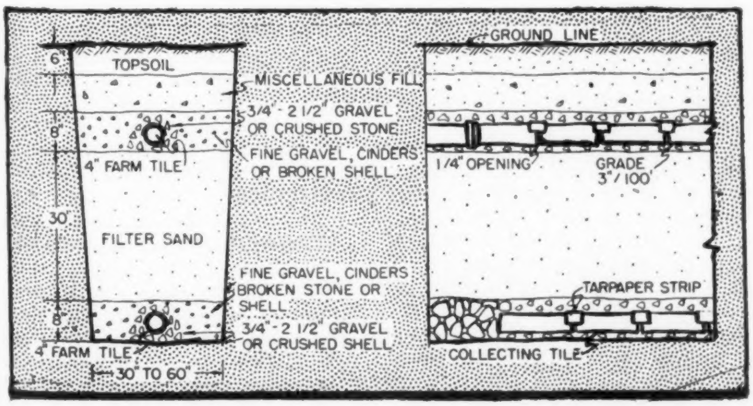
Sand Filter Trenches

When absorption trenches are impractical, subsurface sand filter trenches may be considered. These have a collecting line in the bottom of the trench and a distributing line above; between the two should be placed about 30 ins. of clean coarse sand, all passing a ¼-inch mesh, and having an effective size of 0.25 to 0.50 mm. and a uniformity coefficient not greater than 4. The trench should be from 30 ins. to 60 ins. wide. Upper and lower tiles should be surrounded with broken stone or gravel to aid in distribution. For all-year service, design may be based on a rate of 50,000 gallons per acre of sand surface per day. Distributor slope should be about 0.5% and collector slope a little greater. In this method of treatment, the sewage is not absorbed. and a free outlet is essential. While a considerable degree of treatment is obtained, care is necessary in the final discharge of the effluent.

Sand filter trenches become uneconomical, as a rule, when the amount of sewage and consequently the length of trench is great enough to require a dosing tank and siphon, that is, when the flow of sewage is greatly in excess of 500 gals per day.

Subsurface Sand Filters

For larger installations, subsurface sand filters may be used. These consist of underdrains, a layer of sand, distribution lines and an earth



Construction features of an underdrained sand filter trench

cover. The sand specifications are the same as for the filter trench and the depth of sand is also normally 30 ins. For year-around usage, design should be based on an application rate of 50,000 gals, per acre of sand surface per day; but for installations used only seasonally, higher rates may be permissible. Dosing tanks should be provided where the total filter area exceeds 1800 sq. ft. and the distributor length exceeds 300 lineal ft. With more than 800 ft. of distributors, two siphons should be used. Both underdrains and distributors should be laid on about 6-ft. centers and should be staggered. Porous material should be continuous over both the surface and the bottom; the bottom should preferably slope toward the underdrains.

Other Treatment Procedures

Brief data are also given on the open sand filters used in many municipalities in the past. Information is also given on chlorination, including equipment and methods.

Grease traps are discussed and examples of design are given. A net capacity of about 2½ gals per person, with a minimum capacity of 30 gals, is recommended.

Illustrative Example of Design for Hotel

An illustrative example of design for a hotel having 20 rooms with private baths and a total of 23 toilets is given. Daily sewage flow is estimated as follows:

20 rooms, private baths, 2 persons each, at 100 gpd	4,000 gals.
5 daytime employees at 25 gpd	125 "
2 night employees at 25 gpd	50 "
Kitchen wastes, assume 60 persons, 180 meals per day at 2½ gals. each	450 "
Total daily sewage flow	4,625 gals.

The percolation test shows a drop of water in the test hole of 1 inch in 7½ minutes; **t** is 6; **C** is 7½ + 6.24 ÷ 29, or 0.475. The required trench bottom area is 0.475 X 4625, or 2,200 sq. ft. With a trench width of 2 ft., the total trench length is 1,100 ft. This requires a dosing tank and alternating siphons, with twin fields, each having a lateral length of 550 ft. Using lateral length of 80 ft., each field will require 7 lines of laterals. If these are placed 6 ft. on centers, an area about 80 ft. square will be required for disposal.

Successful Filter Fly Control

(Continued from page 39)

time increases the efficiency of the treatment and yields substantial economies over batch methods. Therefore, Ridgewood purchased a Proportioneers Adjust-o-feeder, which is resistant to any action of DDT or its carrying agents. This unit has a capacity up to 7.2 ghp and is extremely flexible, permitting precise control at any desired concentration, and capable of use over a wide range of dosage or sewage flows.

Another Psychoda Enters the Picture and Causes Trouble

An excellent degree of control was effected from May 12 to Aug. 18, 1947, without interruption to operation or deterioration of effluent quality. Then, quite suddenly, DDT failed to function as before. There was no change in plant conditions, but it had been noted that the psychoda were of a smaller, less "hairy" variety, with quite different wing structure. Identification of the psychoda indicated that the predominant species during the early part of the year has been *P. albipunctatus*, while the late summer variety was *P. alternata*. Both are normally found in filters, but one or the other appears always to predominate. We had apparently controlled albipunctatus only to find that DDT-resistant alternata had assumed the majority role.

The 1948 psychoda open season began in April, and DDT was again tried, but without success, even though we used concentrations as high as 34 ppm, or nearly three times as great as the original successful dosage. Thereafter, we tried, without success, numerous other compounds including Isotox, Vapotone, Chloroben and Nacconal. A trial was made with Pennco BHC E-9 (benzenehexachloride), but a heavy rain rendered the results inconclusive. Adults were reduced by a "fogging" application by the courtesy of Fog, Inc., a subsidiary of Todd Shipyards Corp., and it was decided to try BHC again.

In this test, the dosing tank, filter and final clarifier were taken out of service so that only 25,000 gallons of liquid remained in them. To this was added 15 gals. of BHC E-11, with 2 quarts of emulsifier and the whole was recirculated through the filter for 12 hours. This resulted in the entire area of the filter being dosed once an hour, with 10 minutes application and 50 minutes rest or contact, and a 600 ppm BHC concentration.

Getting Results With Benzenehexachloride

The application was a complete success. The filter media was completely covered with dead and dying larvae and control was accomplished without the need for any marginal spraying. Clarification was impaired for four days, but no sloughing of solids occurred and BOD removal was maintained at a normal 96%. Control for 28 days was accomplished by this treatment. In the next application, only 10 gals. of BHC were used, and this treatment gave control until Nov. 8. An application of five gallons was made then, and this closed out the work for 1948.

The use of benzenehexachloride, in which the active ingredient is essentially the gamma isomer, together with prolonged contact, gave us highly effective control. The concentrations used may possibly be reduced, for the minimum amount necessary for control has not been determined, nor do we know that we have established the most effective contact time. Our concentration of 600 ppm to 666 ppm gives 66 ppm to 73 ppm of gamma isomer when using BHC-11, which contains 11% of the isomer.

Reducing Fly Population at Dumps

Newark, N. J., during its latest fiscal year collected more than 1.2 million cu. yd. of refuse; most of which, together with street dirt, was dumped on low meadow land. An effort at fly control at the dumps was begun in 1947 by the Health Department and continued with marked success. A careful inspection and count had disclosed that there was an average of 100 flies per sq. yd. in the dump area, and the trucks were literally swarming with them. A 5% DDT water emulsion was sprayed weekly over the dump and the trucks, using a large tree-spraying truck. Two weeks after this treatment started, the fly population at the dumps had been reduced at least 70%, and the trucks were practically free of them.

Better Bituminous Pavements

(Continued from page 27)

¾" to No. 16 aggregate and 0.43 to 0.46 gallon of RC-2 per square yard. The cut back is applied in two equal applications, the aggregate being spread and allowed to dry after the first. The aggregate is coated with asphalt by dragging with a heavy long-base broom drag. The surface is rolled and allowed to cure before opening to traffic. A tighter surface may be obtained by spreading 5 to 7 pounds of seal aggregate or sand per square yard and rolling again. This also permits opening the road considerably sooner. The advantages of the drag seal include a smoother surface, protection of the surface from abrasion by coating the aggregate, and practically no loss of seal aggregate.

Appropriate grades of tar or emulsified asphalt may, of course, be used in both types of surface treatment.

Cold mix sand asphalt provides a relatively inexpensive pavement for use in those localities where local sand is available. This type is especially suitable where a reasonably well graded sand occurs in the subgrade. The pavement is usually constructed to a thickness of 3 to 5 inches by mixing the aggregate and rapid curing cut back asphalt with traveling plants. The bitumen content is from 4 to 6 per cent. The mix is spread and cured with motor graders, disc harrows and rotary mixers, following which it is rolled with pneumatic tired and tandem rollers. A prepared base is not used under the pavement as the mix serves as a base and wearing surface. When constructed over clay subgrade, an insulating layer of sandy material is used beneath the pavement.

The hot plant mix pavements are considered to be the highest type of all bituminous pavements. The improvements in equipment for mixing, and laying hot mix material in the last dozen years have not only reduced their comparative cost but widely extended their usefulness.

The North Carolina Highway Commission has been using hot sand asphalt for new construction, widening and resurfacing for a long period with excellent results. The specification below shows the composition of mixtures for three different gradings of sand asphalt surface course material.

Sand Asphalt Surface Course

The fine aggregate and bituminous material shall be combined in such proportions as to produce a mixture conforming to the composition limits by weight for Grading A, B, or C, whichever is called for in the special provisions, as shown in Table I.

The sand asphalt base material has the same gradings except that no mineral filler is required and the bitumen content is 4.5 to 7.5%. The asphalt used is 85-100 penetration. Inclusion of wide gradation limits permit the use of local sand or screenings for aggregate in the majority of cases.

Sand asphalt surface course is placed 1 to 1.5 inches compacted thickness on a sand asphalt base 1 to 3 inches thick or on some other type of base or old pavement.

When used to widen and resurface existing pavement the sand asphalt base material is placed on the prepared subgrade or base course in the trench along the old pavement with a mechanical finishing machine. Usually it is desirable to place a wedge course over the old pavement in the same operation. This is covered with an additional leveling course of 1-inch of base material then with 1-inch of surface course.

The widening and wedge course is placed on the entire project first, then all of the leveling course is placed before any of the surface course. In this way the first two courses receive compaction by traffic before the final course is placed. A tack coat of rapid curing cut back asphalt is applied to the surface and vertical edges of the old pavement and tack coats of hot asphalt cement (85-100 penetration) are used between the other two layers.

There has been a hesitancy on the part of some engineers to use a flexible pavement for widening a rigid type; however the method described has proven successful on highways carrying a large volume of heavy traffic.

For the past three years North Carolina has been constructing a considerable mileage of secondary roads using one inch of sand asphalt surface course on a prepared base. The base is primed with medium curing cut back and this is allowed to cure. No tack coat is used. Admittedly this is "slicing the cake" pretty thin but where the bases have been properly prepared this pavement is holding up very well.

When local aggregates are not available, bituminous concrete binder and surface course mixes are recommended. These should always be specified for locations where maximum stability is required. Excellent specifications for these mixes are available (from The Asphalt Institute, 801 Second Avenue, New York), and will not be set forth here.

Bituminous Pavement Maintenance

The maintenance of bituminous pavements is a relatively simple procedure if the design and construction have been properly handled.

For single and double surface treatments a light retreatment applied at intervals of from three to six years should keep them in good condition as long as the design is adequate for the traffic. When structural failures occur with such frequency as to indicate overloading, a heavier resurfacing consisting of from one to three inches of cold mix sand asphalt or hot plant mix will seal the surface and provide

TABLE I—SAND ASPHALT SURFACE COURSE

Sieve Designation		*Percentage of Total by Weight*		
Passing	*Retained on*	*Grading A*	*Grading B*	*Grading C*
½-inch				100
No. 4		100	100	
No. 4	No. 10	0-10	0-10	0-30
No. 10	No. 40	10-50	5-55	10-45
No. 40	No. 80	25-55	25-70	10-50
No. 80	No. 200	10-35	5-50	10-40
No. 200		5-10	2-10	5-10
Bitumen		7-10	7-10	7-10
Clay in Aggregate by elutriation, Max.		6	8	8

The above mixtures shall be varied within the limits designated as directed by the Engineer. The bitumen content shall not vary more than 0.5%, plus or minus, from the amount prescribed by the Engineer.

additional slab strength to carry the increased loads.

The purpose of the light retreatments is to prevent the bituminous surface from becoming brittle due to oxidation and to seal small cracks. The easiest of these retreatments to apply is a sand seal consisting of 0.18 to 0.25 gallon of RC-2 covered with 10 to 12 pounds of coarse sand or stone screenings per square yard. The cut back asphalt will not take up all of the cover material and the excess should be kept uniformly spread by dragging with a light broom drag until the RC-2 has thoroughly cured. When properly done this treatment will not be slick, as the surface will have a sand paper texture which provides splendid skid resistance.

The only difficult feature of the sand seal is to obtain a uniformly light spread of the cover material. To overcome this, an employee of the North Carolina Highway Commission, A. T. Hight, developed a device for vibrating a simple tailgate spreader with a concrete vibrator. This equipment is now in use throughout the State and is called the Hight Uni-Spreader. It greatly speeds up the application of the sand seal as well as resulting in a considerable saving in aggregate.

A heavier retreatment which gives good results is the drag retreatment. This is applied in a manner similar to the drag seal on the Double Bituminous Surfacing and consists of 30 pounds of ¾" to No. 16 aggregate and 0.4 to 0.45 gallon of RC-2 per square yard. After dragging and rolling, the surface should be choked with 5 pounds of sand per square yard.

As previously referred to, the heaviest retreatments consist of cold or hot mix retreads and the thickness is varied depending on the condition of the old pavement.

Repairing and Patching Bituminous Pavements

The proper patching of bituminous pavements is an essential of good maintenance. When small surface cracks appear in surface treatment they should be sealed promptly with a light application of bituminous material and covered with sand. If neglected they permit water to reach the base and are almost certain to result in complete failure of the pavement.

In repairing base failures the unstable base material should be removed down to a firm foundation and the excavation filled with selected soil base or crushed aggregate. When the base is thoroughly compacted a bituminous patch can be placed.

The edges of all patches should be cut to straight lines with vertical sides and care must be taken to obtain a water tight seal between the old surface and the patch.

A good cold patch material can be prepared by mixing equal parts of ¾" to No. 16 aggregate and sand with 18 to 20 gallons of RC-2 per ton of aggregate. The mixing can be done on a section of pavement with a motor grader or in a small mixer. The mix should be allowed to cure for several days before being used and may be kept in usable condition for months if placed in a pile and covered. The coating of damp aggregate, during mixing, is facilitated by the use of an additive in the cut back. There are several materials for this purpose now on the market.

Hot plant mix material, of course, is excellent for patching when available. Bituminous patches of mixed materials should have a minimum thickness of about 1½".

For patching on poor subgrades, or where other persistent failures occur, soil cement has proven very effective. The mix can be prepared in a concrete mixer or pugmill and by using granite screenings with about 8% cement, a mix is obtained which works nicely and does not clog the mixer as much as when most soils are used. The use of pneumatic tampers for compacting the mix is recommended for best results.

Engineers concerned with bituminous pavements should be constantly on the alert for improvements in methods of construction and maintenance that will reduce costs and improve results. Judicious use should be made of local materials for bases and surface courses and the whole process flavored with a load of good common horse sense because the demand for paved roads is far in excess of the supply.

Operation Data From Richmond-Sunset Sewage Treatment Plant

The Richmond-Sunset sewage treatment plant in San Francisco, Calif., handled 3,679.9 million gallons of sewage during the fiscal year 1948. Screenings amounted to 1.45 cu. ft. per million gallons; sand averaged 0.32 cu. yd. or about 9 cu. ft. per mg.; suspended solids removal averaged 67%, from 240 ppm. raw to 80 ppm. in the primary effluent; BOD removal averaged 40%, from 240 ppm to 145 ppm. Gas production averaged 1 cu. ft. per capita per day.

Stream Pollution by Abattoirs

The Pennsylvania Department of Health has investigated approximately 250 abattoirs and slaughter houses located in the most heavily populated areas of the eastern section of the state and finds that practically all large abattoirs and packing houses located in the cities covered by the survey discharge their wastes to the city sewers. In those cases the responsibility for treatment of the wastes rests with the city which permits the use of the sewers for this purpose. Present indications are that in the outlying areas a comparatively small number of the slaughtering establishments pollute the streams. Pollution is prevented by the use of cesspools and septic tanks, to which those wastes which are not sold to rendering concerns are discharged. When the flow to the cesspools and tanks becomes too heavy for leaching through the soil, the liquid is pumped from the containers and used as fertilizer on the farm land.

Research to develop a practical method for the treatment of wastes from small slaughter houses is being carried on at an experimental plant built at Western State Penitentiary, Rockview, under the direction of Pennsylvania State College through an agreement with the Sanitary Water Board. The program was inaugurated because it is frequently difficult to apply methods of waste treatment employed in large abattoirs to small establishments.

Making Turf Shoulders

In the highway field, stabilized bases for turf shoulders is an important subject. Michigan road beds are topped off with free draining sands and gravels unless the soils in place are sandy. This granular subbase extends through the shoulder to provide continuous drainage into the roadside ditches. In stabilizing the resulting sand and gravel shoulder the usual procedure on all but the heaviest traveled roads calls for placing three inches of salvaged top soil on the shoulder and then mixing this with the underlying sand or gravel to a depth of six inches. The result is a shoulder which combines fair stability with fair grass growing capacity. Stockpiling top-soil during construction operations kills much of the life in it which in turn reduces its productivity. For this reason stockpiles should be kept as small as possible.—From a paper before the Am. Road Builders Ass'n by Olaf L. Stokstad, Engr. of Soils, Michigan H'way Dept.

CITY-COUNTY
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ENGINEERING
DATA

Vacuum Filter Operation at San Francisco Sewage Treatment Plant

More than 5 million gallons of sludge were filtered during the year ending June, 1948, at the Richmond-Sunset Sewage Treatment Plant, San Francisco, Calif. Solids in the sludge averaged 3.26%, of which 67.5% were volatile. An average of ferric chloride used for sludge conditioning before filtration was 3.56% of the dry solids. The production of sludge cake, in terms of dry solids per square foot of filter per hour, averaged 4.90, and the filter cake contained 74.1% of moisture.

Cost of Laying Water Pipe

In the 1948 report of the Augusta, Me., Water District, S. S. Anthony, Superintendent and Engineer, gives cost data on laying 6-inch and 8-inch water mains. In the Eastern Division, 1,724 ft. of 6-inch main were laid, this including eight 6-inch and one 2-inch valves, at a cost of $1.90 per foot for materials, 74c per foot for labor, and 29c per ft. for equipment and miscellaneous. This was a total, for 6-inch pipe, of $2.93 per ft.

In the Western Division, an 8-inch main 1,337 ft. long, with two 8-inch gate valves, was laid at a cost per ft. of $2.46 for material, $1.64 for labor, and 24c for other costs, a total of $4.34 per ft. Another 8-inch main in this section, 1,107 ft. long, with two 8-inch and one 6-inch valves, was laid at a cost of $3.65 per ft., the labor cost being only 96c per ft.

In the Northern Division, 2,220 ft. of 8-inch pipe, with four 8-inch valves, were laid at a cost of $3.06 for materials, $2.49 for labor and 95c for equipment, a total of $6.50 per ft. This work included a considerable amount of rock excavation, which accounted for the higher cost.

Average Bid Prices for Highway Construction in 1948

The Public Roads Administration has issued a summary of the average bid prices on various items of road construction, based on secondary projects let during 1948. Common excavation averaged 33c per yd., but in the northeastern states averaged 66c, ranging from 59c in Rhode Island to 91c in New Jersey. Structural excavation, common, dry, averaged $3.59 per cu. yd. for the country as a whole; in the northeast it was $3.97. Clay pipe, 6-inch, averaged

$1.50 per ft., but in New York averaged only $1.07; 24-inch r.c. pipe averaged $4.90 per ft., with northeastern states prices averaging $7.07; 24-inch galvanized iron pipe averaged $4.50, but in the northeast was $6.71. Structural concrete averaged: For superstructures, $49.72 per yd.; for substructures, $49.12; and for foundations and footings, $45.95. Summaries also have been released for urban projects and for general highway construction.

Rebuilding Softening Plant Saves Money in Operation

New Franklin, Mo., found its softening plant was unable to meet the needs for water. Herbert Wolcott, water engineer of Columbia, Mo., was employed to determine the needs of the community. He found that the zeolite softener was producing only 6,000 gals. per regeneration, as compared to its original capacity of 30,000 gals. The unit was completely cleaned and reconditioned, and a high capacity resin zeolite was installed. He reports that the softener now has a capacity of 127,000 gals. per regeneration, and the savings on salt used will be approximately 30%. Total cost of the work was $2,700. W. H. Bowman is mayor of New Franklin.

Oklahoma Highway Costs Lower

The Oklahoma State Highway Commission. H. E. Bailey, State Highway Director, reports that the April contract letting was the sixth consecutive letting at which combined low bids fell below the engineering estimates. Since October, contracts have been awarded for 563.9 miles of construction at a cost of $12,155,384, which was $968,931 under the estimated costs.

Tests Show Connections Do Not Weaken Precast Concrete Pipe

Reinforced concrete pipe, manufactured by the centrifugally spun method, has been used by the City of San Francisco for several sewer contracts in recent years due to savings in cost and installation time as compared with monolithic concrete sewers. The installation of the reinforced concrete pipe has presented no difficulty or problem where there were no side sewers to be connected to the pipe in the field, as in storm overflow lines, or in new sewer lines in unoccupied areas where openings for side sewers could be precast in the pipe.

With the cooperation of one of the leading pipe manufacturers, a series of tests was arranged to assist in determining the suitability of the precast pipe in cases where numerous openings for side sewers must necessarily be cut in the field. Several sections of 30" reinforced pipe were tested in compression. Some had precast holes through the wall and others had holes cut subsequent to casting and curing. All of the holes were 11½ inches in diameter. The tests indicated that the pipe had the same strength whether the holes were formed or cut; furthermore that there was no measurable difference in strength between pipes having holes through the wall and pipes without holes. Based on these tests and other studies, the precast pipe was specified for a portion of the Scott Street Sewer with the idea of determining definitely what difficulties may arise on the job in placing this type of pipe and making the necessary field connections.

Winter Highway Maintenance in Vermont

Although Vermont is decidedly a snow-belt state, of the 1804 miles of its state highway system all but 7 miles are maintained in winter. Also, of the 2,749 miles of State-aid highways, 2,649 were kept open during the winter of 1947-1948; and of the 9,538 miles of town highways, 7,435 miles were kept open. Thus a total of 11,881 miles was kept open. The cost of this work on the state highway system averaged $165 per mile for plowing snow, $295 for applying sand and chemicals, $20 for snow fence, and $116 for miscellaneous items; a total of $1,075,255. In addition, the state gives financial aid for winter maintenance: one half the cost up to $50 per mile for "state-aid" roads, and one half the cost up to $25 a mile for town highways.

Street Maintenance

(Continued from page 36)

been placed on either a permanent type paving or asphalt penetration street, the surfacing crews complete the repair. In case of concrete base cuts, hot mix asphaltic concrete is placed; and on gravel bases, a triple course asphalt surface treatment is applied. On this work, planning, organization, and control are necessary to prevent loss of time and duplication of effort.

Crack Pouring and Filling

The smaller cracks on all permanent type asphalt streets are filled with an OA 135 asphalt. The cracks are cleaned by hand, using a wire broom, and a 600-gallon asphalt distributor, equipped with a special nozzle and hose, is used in the application. Pump pressure on the distributor is lowered in an effort to avoid wasting the asphalt. After the cracks have been filled, a fine chat and dust is used for coverage. Where cracks are too wide to pour, the joint is cleaned out, a tack coat applied and the joint is filled with cold mix rock asphalt. Prior to 1947, the city used 90 to 100 penetration asphalt on all maintenance work; since that period, an OA 135 asphalt has been used and the softer asphalt has proven to be more suitable for Fort Worth's particular needs.

The above are by no means all of Fort Worth's street maintenance problems, nor are the ones enumerated herein considered to be completely solved, but it is believed that a partial solution has evolved and a step in the right direction has been made.

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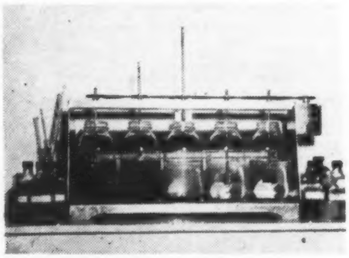


The Tyus coagulator.

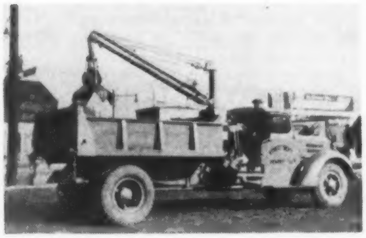
The Tyus Coagulator for Water Testing

The purpose of this coagulator is to make it simpler and easier to determine the correct chemical dosage required for water treatment. There are five containers. The minimum probable dosage required is placed in the first container and increasing amounts in the others. The coagulator is then placed in operation to determine which dosage gives the best results. The coagulating process is clearly shown by the fluorescent light reflected through the water sample. Any particular sample may be removed without disturbing the work on the others. For fuller information write Bill H. Tyus, 704 S 7th Ave., Teague, Texas.

Use coupon on page 93; write in No. 5-1

Catch Basin Cleaning Faster and Cheaper

One man does the whole job of catch basin cleaning with this outfit, and does it without the usual mess



One-man catch basin cleaner.

and spillage. A power swing boom crane with a deep-lip orange-peel bucket is mounted behind the cab of a standard truck, or on the front of a suitable wheel tractor. One man lowers the bucket into the manhole, raises the filled bucket, swings the boom, and dumps the collected material into the truck or other container. Can be installed on a new truck or on a truck already in service. With the bucket removed, the crane can be used for handling pipe, hydrants, manhole frames or covers, or other heavy objects up to 3,000 pounds at 8-ft. radius. For full information, write Silent Hoist & Crane Co., Brooklyn 20, New York.

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New Jaeger Bituminous Paver

This new bituminous paver lays any mix, hot or cold, dense or open texture, and gives uniform densities and smooth riding. It lays any width of pavement from 5'8" to 12'6" without removal or insertion of any parts, and is almost instantly adjustable for width without stopping the machine. The joint with the adjacent course or with curb and gutter is hydraulically and automatically matched. Any mat thickness up to 6 ins. can be laid. The long straight-edge stabilizing runners and hydraulic leveling pans insure a precision smoothness. The paver is crawler-mounted. Quick crown changes from 2" convex to 1" concave can be made. For full information ask for Catalog BP-9. Jaeger Machine Co., Columbus 16, Ohio.

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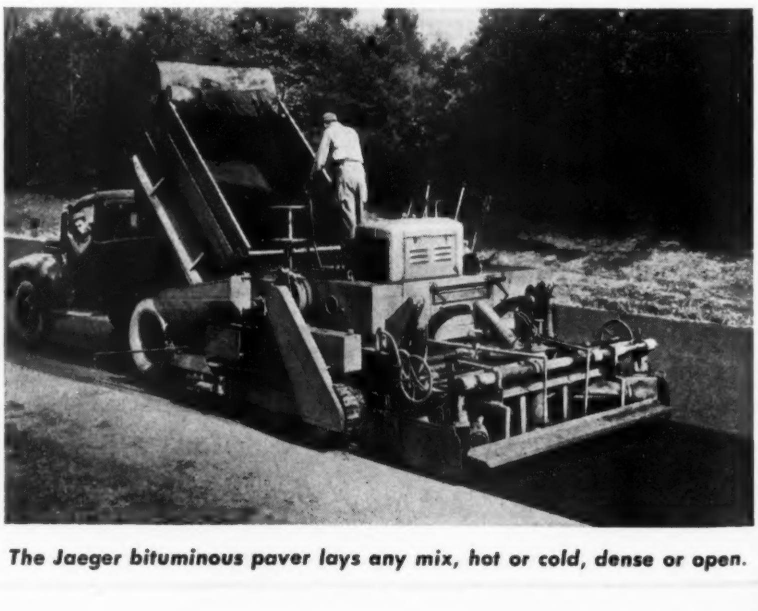
Using the Warsop breaker.

Warsop Self-Contained Paving Breaker

This is a gasoline driven breaker, complete in itself. It weighs about 90 pounds and is designed for breaking



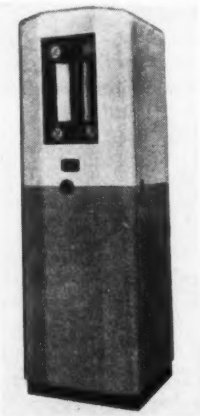
The Jaeger bituminous paver lays any mix, hot or cold, dense or open.

concrete, general demolition, trench spading, asphalt cutting, ramming, breaking frozen ground and light driving. A rock drill is also available. For use at altitudes above 3000 ft., a special distance piece is furnished which reduces the area of compression chamber Full data from Warsop Power Tools, Inc., 347 N. Twelfth St., Philadelphia, Pa.

Use coupon on page 93; write in No. 5-4

Chlorine Gas Feeder by Builders

The Chlorinizer, a new chlorine gas feeder, has been announced by Builders-Providence. This unit meters chlorine gas to produce chlorine water solutions. A positive chlorine



Builders chlorine gas feeder.

rate indicator, with a direct reading linear scale is provided, and the design is such as to insure completely safe and highly accurate operation. The chlorinizer is readily adapted to semi-automatic, program or automatic proportional operation. Conversion from one method of operation to another may be made readily in the field. Full information on sizes and types is available from Builders-Providence, Providence, R. I.

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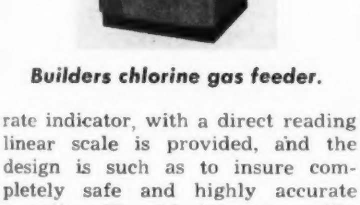
Sanitary Compressed-Loading Garbage Collector

Loading into this unit, because of the wide and low loading hopper, is fast and economical. Compression loading gives greater capacity because the com-



How the Sicard Sanivan dumps.

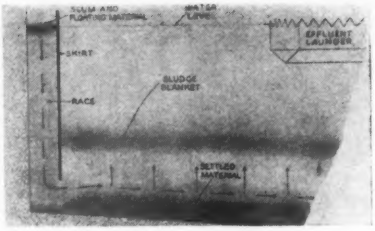
pression is applied every time the 1-yd. hopper is emptied. Loading height is 34 ins. Compression and loading are controlled from the rear. Special provision for dumping permits unloading at the edge of the disposal dump or on an incline. A folder describes this modern unit. *Sicard Industries, Inc., Watertown, N. Y.*

Use coupon on page 93; write in No. 5-6

Spiraflo Clarifier for Sewage or Water Treatment

In this clarifier, the incoming sewage is introduced tangentially into an annular race which extends entirely around the tank. The manufacturer reports results at three plants. In one, at an army cantonment, with the raw sewage having a BOD of 336 and an SS of 320, BOD removal was 65.5% and SS removal was 76.7%. A city reported removal of 56% of BOD with a raw sewage strength of 225 ppm. BOD. At a third plant, BOD removal was said to be 65.5%. Positive grease removal and construction savings are also stated as advantages of this design. Ask for Bulletin 6790, *Yeomans Bros. Co., 1411 N. Dayton St., Chicago 22, Ill.*

Use coupon on page 93; write in No. 5-7



Spiraflo clarifier section.

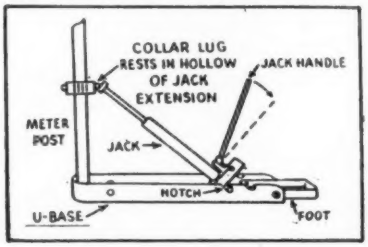
Pre-Molded Rubberized Sealing Strip

A pre-molded para-plastic rubberized asphalt sealing strip has been developed especially for sealing vertical and overhead concrete joints. It is claimed this will give a water-tight joint. The strip can be nailed to the form, or it can be attached to the concrete by heating until it is tacky, or by freshening with gasoline or kerosene. These strips include: "Para-lateral" for vertical and overhead joints; "Baseal" for expansion and contraction joints at the subgrade; and "Para-plastic coated sponge rubber" a pressure seal for vertical angles and overhead joints. Servicised Products Corp., Chicago, Ill.

Use coupon on page 93; write in No. 5-8

Straightens Meter and Sign Posts Quickly

This new "postratner" cuts time and costs on straightening bent meter and highway sign posts, as well as any other metal posts, as at water works or sewerage plants. It is claimed that the average bent post can be straightened for as little as 6 cents. Weighs 60 pounds and can be carried easily. Operated by one man. Usable on any type of meter post. A 4-page bulletin tells all about it and gives specific directions for all kinds of bends. Barber Postratner Co., 112 Irving St., New Haven 13, Conn.



The Barber "Postratner."

Use coupon on page 93; write in No. 5-9.

PERSONAL AND INDUSTRIAL

Cochrane Corp., Philadelphia, Pa., has acquired Liquid Conditioning Corp., Linden, N. J., and will operate it as a wholly owned subsidiary, S. B. Applebaum, well known in the field of water conditioning, will have charge of cold water conditioning activities for the combined organization.

Layne & Bowler, Inc., Memphis, Tenn., have announced the addition to the Layne organization of the General Filter Co., Ames, Ia.

Samuel & Hirschberg, 204 Valentine St., Hackettstown, N. J., have acquired the manufacturing rights for the line striping equipment formerly manufactured by Industrial Tool & Products Corp., Rochester, N. Y.

Filtration Fabrics Division, 155 Oraton St., Newark 4, N. J., has been organized by Filtration Engineers, Inc., to provide better filter cloths for all types of filters and processes.

William G. Carter, formerly of the Natonal Gypsum Co. staff has joined the Buffalo Meter Co., and will have headquarters in Buffalo, N. Y.

R. D. Carnahan, formerly with the Bradentown, Fla., water treatment plant, and a Navy veteran, has been appointed Manager of Industrial Equipment for the Stover Water Softener Co. Mr. Carnahan will continue to live in Bradentown.

W. A. Hammond has been elected vice-president of the Marion Metal Products Co., Marion, Ohio.

Robert & Co. , Inc., consulting engineers of Atlanta, Ga., have moved from the Bona Allen Bldg. to 96 Poplar St., N. W., Atlanta 3, Ga.

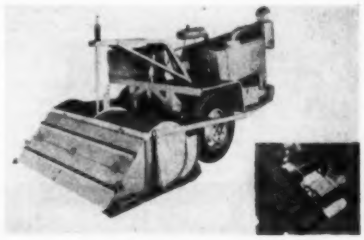
ASSOCIATIONS

The spring meeting of the New York State Sewage Works Association will be held at the Governor Clinton Hotel, Kingston, N. Y., on June 6 and 7. R. C. Sweeney, State Department of Health, Rochester, N. Y., is secretary.

A research symposium on Water, Sewage and Industrial Waste will be held in Washington, D. C., on June 23 and 24. The meeting, which will be sponsored by the Sanitation Study Section of the National Institute of Health, will be held in the Dep't of Agriculture auditorium, 14th and Constitution Ave. C. C. Ruchhoft, 1006 Broadway, Cincinnati, O., is chairman.

The Central States Sewage Works Ass'n will meet at the Hotel Sherman, Chicago, Ill., June 17 and 18. P. W. Reed, 1098 West Michigan St., Indianapolis 7, Ind., is secretary.

The American Public Health Association will hold its annual meeting in New York City, October 24-28. Each of the 13 sections will hold numerous meetings, and about 20 associated organizations will also hold meetings at the same time. Information can be obtained from Dr. R. M. Atwater, APHA, 1790 Broadway, New York.



Seaman pulvi-mixer with selective speed transmission.

★ ★ INDEX OF ADVERTISEMENTS ★ ★

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NEW LISTINGS

Complete Sanitation and Process Equipment Bulletin

20. A new illustrated Bulletin gives detailed information on all "Rex" sanitation and process equipment. 36 pages give engineering data, tables, conversion factors. Ask for Bulletin 48-41, Dept. PW, Chain Belt Co., 1600 West Bruce St., Milwaukee 4, Wisc.

Permanent, Corrosion Resisting Filter Plant Underdrains

77. A tile filter bottom of glazed fire clay blocks is corrosion-free, has low head loss, and assures uniform filtration and wash water distribution. Investigate for filter rebuilding or new construction. F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.

Book Tells How to Control Algae

89. Details on the control of various microscopic organisms frequently found in water supplies, and the elimination of tastes and odors, are discussed in the enlarged edition of "The Uses of Copper Sulphate in the Control of Microscopic Organisms." For your free copy write Phelps Dodge Refining Co., Dept. PW, 40 Wall St., New York 5, N. Y.

Get List of Lime Suppliers

150. Check the convenient plant locations in your vicinity for suppliers of lime for water and sewage treatment. Write National Lime Association, 927 Fifteenth St. N. W., Washington 5, D. C.

Continuous Operation Trojan Pipe Pusher

151. New, larger pipe pusher and puller handles pipe up to 2", has three pushing speeds. Fittings handle lead and copper pipe too. Get full details showing how to speed up water service installations. Write Trojan Mfg. Co., 441 E. Water Street, Troy, Ohio.

Truck or Tractor Mounted Catch Basin Cleaners

153. Both tractor and truck type, full powered Silent Hoist catch basin cleaners are available to speed your maintenance job. Investigate these units, complete and ready for mounting on your truck, or already installed on "Krane-Kar" tractor. Get Bulletin 67 from Silent Hoist & Crane Co., Dept. PW, 844 63rd St., Brooklyn 20, N. Y.

Low Cost Power From Dual Fuel Engines

154. Operating on the Diesel cycle, burning either oil or gas, the Worthington Supercharged Dual Fuel Diesels give high economies by running on the cheapest fuel available. Get complete data from Worthington Pump & Machinery Corp., Dept. PW, Harrison, N. J.

Plant Layouts for Incinerator Installations

155. Send for this new catalog which shows typical incinerator plant layouts engineered expressly to make use of modern design and equipment. A great help for the designer. Ask for catalog M-1, Washburn & Granger, Inc., 53 Park Place, New York 7, N. Y.

Lime for Water and Sewage Treatment

156. Write today for information on your requirements of high calcium oxide content lime for softening, coagulation, pH control, etc. Data on tested lime products from National Gypsum Co., Buffalo 2, N. Y.

Complete Equipment for the Complete Pool

157. Latest equipment for recirculation, filtration, chlorination, softening and pH control are described in Permutit Bulletin No. 2157. Manual and automatic valves explained and many installations diagrammed. Complete specifications given. Permutit Co., 330 West 42nd St., New York 18, N. Y.

Check "Gunite" Concrete For Every Application

158. Big 44-page book illustrates "Gunite" uses for both repair and new construction of sewers, tanks, dams, swimming pools, and all concrete structures. A multitude of applications. Be sure to check coupon or write Pressure Concrete Co., Dept. PW, 193 Emmet St., Newark, N. J.

STREETS AND HIGHWAYS

Strong, Speedy, Low-Cost Maintainer Has Many Uses

22. BG Maintainer, a powerful speedy, low-priced machine for light road maintenance. Full details in illustrated folder Huber Mfg. Co., Dept. PW., Marion, Ohio

Solve Your Drainage Problems This Easy, Permanent Way

28. Useful new 60 page catalog on standard corrugated pipe, multi-plate pipe and arches and 18 other drainage and related products for culverts, sewers, subdrains, flood control, airports, water supply and other types of construction. Ask for "Armco Products for Engineering Construction," Armco Drainage and Metal Products, Inc., Dept. PW, Middletown, Ohio.

Data on All Types of Bins and Batching Plants

47. Good illustrations and useful data on all types of Heltzel Highway Bins, for truck mixer charging, bulk cement plants, enclosed bucket elevators, belt conveyors, etc. Heltzel Steel Form & Iron Co., Dept. P.W., Warren, O.

Speed Your Work With These Powerful Motor Graders

48. Two powerful Galion motor graders designed to answer every requirement for more speed in road, airport, dam and housing construction work are fully described in a folder illustrated with many action pictures. Issued by Galion Iron Works & Mfg. Co., Galion, Ohio.

Latest Maintenance Equipment For Blacktop Roads

52. "Blacktop Road Maintenance and Construction Equipment" — Asphalt and tar kettles, flue type kettles, spray attachments, tool heaters, surface heaters, road brooms and rollers. This is modern and up-to-date equipment for blacktop airport and road construction and maintenance. Write for Catalog R. Littleford Bros., Inc., 452 East Pearl St., Cincinnati 2, Ohio.

Tractors for Counties, Cities and Contractors

76. An attractive 24-page catalog portrays the Allis-Chalmers HD-5 crawler's abundant capacity and ability to meet the variable needs of counties, townships and contractors. Photographs and cutaway views illustrate its rugged construction and simplified maintenance. Use coupon or write Allis-Chalmers Mfg. Co., Tractor Division, Milwaukee 1, Wisc.

Improved Special Rollers Help Cities and Counties

84. Road and street widening are speeded up with Buffalo-Springfield trench rollers of improved design. Many other

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Booklets from Pages 93-97:

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New Products, Pages 88-90:

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special compacting problems handled by the portable KT-6 model. Get engineering specifications in bulletins TR-3B and KT-6 from Buffalo-Springfield Roller Co., Springfield, Ohio.

How to Beat the Weed Problem

85. Be sure to investigate weed control with selective chemical weed killers. Ask for bulletins on Dolge products that will rid roadsides, parks and lawns of the weed nuisance. C. B. Dolge Co., Dept. PW, Westport, Conn.

Adhesive Joint Sealers and How They Are Applied

130. Learn how joints are prepared and Flintseal Hot-Poured Joint-Sealing compound applied. Series of pictures shows each step and explains every operation for good joint construction. On request from The Flintkote Co., Dept. PW, 30 Rockefeller Plaza, New York 20, N. Y.

Just Right for Fast, Small Asphalt Mixes

90. The Foote Kinetic Mixer delivers 3 cu. ft. in 30 seconds. Portable and easily operated. Get Bulletin K-100 from The Foote Co., 1954 State St., Nunda, N. Y.

Grading Can Be Faster, Cheaper and Easier

96. You'll like every feature of the Austin-Western 99H Grader. It has all-wheel drive, all-wheel steer, controlled traction, precision sideshift and a high lift, extreme reach, reversible blade. Get data from Austin-Western Co., Aurora, Ill.

Light Weight Machine Does Work of Heavy Roller

111. For compacting hot or cold patching material be sure to investigate the Wayer Impactor, 2,000 blows per minute tamps, finishes and cures. All data in Bulletin 25-8. Wayer Impactor Sales Co., 12 N. Third St., Columbus 15, Ohio.

Fast, Efficient Skid-Proofing

114. Get full facts about Baughman Light-Weight Cinder Spreaders, fast operators for cinders, sand, salt, chips, etc. Free flowing at low temperatures. 9-17 cu. yd. capacity. Write Baughman Mfg. Co., Dept. PW, Jerseyville, Ill.

How to Speed Curb and Gutter Work

126. Here's a 24-page bulletin illustrating form set-ups for every type of curb and gutter work. Send for Bulletin 2259 and learn how to speed up the job with Blaw-Knox Steel Street Forms. Write Blaw-Knox, Dept. PW, Farmers Bank Bldg., Pittsburgh 22, Pa.

Uniform Spreading 2 to 10 ft. Wide

136. Saves labor, spreads 0 to 100 lbs. a sq. yd., dusts up to 1" material forward, reverse, on curves, hills or straightaway. Assures uniform, even density of spread. Write for bulletin: Dept. PW., All Purpose Spreader Co., Fuller Road, Elyria, Ohio.

For Speedy Bituminous Maintenance Jobs

142. The Standard Steel trailer-mounted pressure distributor and tank is easy to move for emergency patching, all maintenance. Write for bulletin "S-J" on this fast acting, low cost equipment. Standard Steel Works, Dept. PW, North Kansas City, Mo.

SEWERAGE AND REFUSE

How You Can Clean Sewers From Streets Easily and Inexpensively

23. 32-page illustrated booklet explains how a city can clean its sewers and culverts with its own forces using the up-to-date Flexible Sewer Rod equipment. Illustrates and describes all necessary equipment. Issued by Flexible Sewer Rod Equipment Co., 9059 Venice Boulevard, Los Angeles 34, Calif.

Sanivan Features Faster Refuse Loading, Greater Capacity

31. Compression loading plate on the Sicard Sanivan crushes ordinary loose garbage into ⅓ original space. For clear, cutaway views of this positive compression action and mechanical full discharge get the "Sanivan" bulletin. Write Sicard Industries, Inc., 2055 Bennett Ave., Montreal 4, Canada.

Packaged Sewage Treatment—Just Right for Small Places

36. "Packaged" Sewage Treatment Plants specifically developed for small communities — 100 to 3,000 population. Write for full description and actual operating data for this type of plant. Chicago Pump Co., 2348 Wolfram St., Chicago 18, Ill.

How You Can Dispose Of Sewage Solids

54. Nichols Herreshoff incinerator for complete disposal of sewage solids and industrial wastes — a new booklet illustrates and explains how this Nichols incinerator works. Pictures recent installations. Write Dept. PW, Nichols Engineering and Research Corp., 70 Pine St., New York 5, N. Y.

For Speedy, Nuisance-Free Refuse Collection

55. The Gar Wood "Load Packer" compresses refuse into the front of the collecting body, thus greatly increasing capacity. 9, 12 and 15-yd. sizes. Described in bulletin PW-M-51, Gar Wood Industries, Inc., Wayne Div., Wayne, Mich.

Glazed Clay Blocks for Trickling Filter Underdrains

66. Illustrated bulletin describes the Natco Unifilter block of glazed, hard burned clay for underdraining filter beds. Write National Fireproofing Corp., Pittsburgh 12, Pa., for free copy.

When you need special information—consult the READERS' SERVICE DEPT. on pages 93-97

Odorless Sanitary Septic Tank Cleaning

88. The Gorman-Rupp Odorless Sanitary Cleaning unit combines centrifugal self-priming pump, air-cooled engine and oval tank on a sturdy frame. For full description of this adaptable unit get bulletin 7-ST-11. Gorman-Rupp Co., 120 N. Bowman Ave., Mansfield, Ohio.

Useful Design Data on Sedimentation Tanks

99. "Sedimentation with Dorr Clarifiers" is a complete 36-page illustrated catalog with useful design data. Ask The Dorr Company, Dept. P.W., 570 Lexington Ave., New York 22, N. Y.

Do You Have the Best Possible Sludge Conditioning?

110. "Ferri-Floc," description and instructions for use in coagulation, sludge conditioning and treating industrial wastes, fully treated in a 24-page pamphlet. Tennessee Corp., 619-27 Grant Bldg., Atlanta 1, Ga.

Underdrains—Hidden But Important Filter Components

113. For filter bottoms this firm makes "Armcre" vitrified salt glazed floor blocks which provide ducts occupying 50% of the floor cross-section and air openings aggregating over 24% of the floor area. Described in several leaflets and data sheets. Ayer-McCarel-Reagan Clay Co., Brazil Ind.

Your Laboratory Needs Reliable Equipment

118. Laboratory apparatus and C. P. chemicals; incubators, microscopes, pH meters, turbidimeters, etc. can be obtained from any of the five branches of the Harshaw Scientific Div. Get bulletins from Dept. PW, Harshaw Chemical Co., Cleveland 6, Ohio.

Need Low-Cost Air For Sewage Treatment?

122. New 20-page booklet shows operting and construction features of Rotary Positive Blowers engineered to fit your needs. Air for activated sludge, water treatment; constant vacuum for filtering. Bulletin 22-23-B-13 gives details. Roots-Connersville Blower Corp., 712 Poplar Ave., Connersville, Ind.

How to Make Sewage Plant Grit Suitable for Fill, Roadways

138. The Jeffrey "Jigrit" washer does a thorough job of scrubbing grit free of organic solids. Grit is classified according to size and organics rejected with overflow. 44-page Catalog 775A describes the "Jigrit" and gives engineering data and installation views of grit and sludge collectors, chemical feeders, garbage grinders and other equipment as well. Dept. PW, Jeffrey Mfg. Co., 948 N. Fourth St., Columbus 16, Ohio.

Durable Gratings and Treads Are a Good Investment

147. Gratings for walks around settling tanks and other parts of treatment plants, both out-doors and in, for stairways, floors and balconies, are described in an illustrated 16-page bulletin by Irving Subway Grating Co., 5053 27th St., Long Island City 1, N. Y.

CONSTRUCTION EQUIPMENT

Shovel Or Load With The Dempster Diggster

45. Automotive Hydra-Shovel digs 15 ft. above, 15 in. below grade, features independent hydraulic hoist and crowd action. Capacities 1 cu. yd. for digging solid earth, 1¼, 1½ and 2 cu. yd. for loading all types material. Get information from Dempster Brothers, Inc., 949 Dempster Bldg., Knoxville 17, Tenn.

Contractors' Pump Features Carryability

93. To find out how well a Homelite Carryable Pump handles large volumes, seepage, mud, write today for illustrated bulletin L-503 containing data of great value to all pump users. Write Dept. PW, Homelite Corp., 2102 Riverdale Ave., Port Chester, N. Y.

52-Page Data-Packed Bulletin On Contractors Pumps

95. Tables for pump size determination on every excavation job, pipe friction loss, altitude effects and lots of other valuable data are included in this comprehensive booklet illustrating the many Jaeger "sure-prime" pump applications. Get your copy (catalog P45) by checking our coupon or writing the Jaeger Machine Co., Dept. PW, Columbus 16, Ohio.

The Right Tractor For Your Job

116. Whether you need a front-end loader, snow plow, bulldozer, sweeper or mover, International wheel tractors combine correctly with allied equipment to do the job. Your choice of gasoline or diesel units is illustrated in Bulletin A-103JJ. International Harvester Co., 180 No. Michigan Ave., Chicago 1, Ill.

Air Cooled Engines for Hundreds of Applications

137. Tested under severest conditions of long, hard use, these engines have earned world wide recognition as the "right" power for hundreds of applications. Get latest bulletin from Dept. PW, Briggs and Stratton Corp., Milwaukee 1, Wisc.

Concrete Forms For Every Need

94. There's a form for your need whether it's concrete pipe for sewer, drain or irrigation; forms for roads, bridges, tunnels or manholes; or a special form problem. For folders telling just what these concrete forms can do for you write Dept. PW, Irvington Form & Tank Corp., 43 Cedar Street, New York 5, N. Y.

High-Speed Dirt Moving Means Lower Costs

149. The '49 Heiliner combines a powerful diesel engine, easy handling hydraulic steering to speed up dirt moving with interchangeable scraper and bottom dump wagon. To learn all the money-saving advantages get bulletin RM 48031 from The Heil Co., Dept. 4439, 3044 W. Montana St., Milwaukee 1, Wisc.

POWER AND LIGHT

Dual Fuel Engines for Municipal Power

19. A new 8-page illustrated bulletin, No. 4811, describes Superior Dual Fuel Diesel engine operation and illustrates the simplicity of controls with fuel conversion by either push buttons or hand lever. Copies are available from Superior Engine Div., Dept. PW, The National Supply Co., Springfield, Ohio.

Diesel Engines With Opposed Pistons

143. The opposed-piston idea is joined with principles of diesel combustion to provide economical operation in municipal, private utility and commercial power plant applications. You'll find colorful, detailed data on this remarkable diesel engine in Bulletin 3800D-1, Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago 5, Ill.

WATER WORKS

Is Your City Metered 100%?

33. 100% metering as practiced by many cities requires accurate, dependable meters with interchangeable parts. Cutaway views of every part, capacity and size data are all included in handsome American-Niagara water meter booklet available from Buffalo Meter Co., 2920 Main St., Buffalo 14, N. Y.

Your Property Is Worth Good Protection

39. When installing link fence you want protection against rust and corrosion as well as vandalism. Investigate chain link fence made of "Konik" metal described in "Planned Protection" published by Continental Steel Corp., Kokomo, Ind.

inal Geophone leak locator, Little Wonder pipe phone, and the Magnetite Dipping Needle. Globe Phone Mfg. Corp., Dept. P, Reading, Mass.

Chem-O-Feeders for Automatic Chemical Feeding

60. For chlorinating water supplies, sewage plants, swimming pools and feeding practically any chemical used in sanitation, treatment of water and sewage. Flow of water controls dosage of chemical; reagent feed is immediately adjustable. Starts and stops automatically. Literature from % Proportioneers, Inc. %, 96 Codding St., Providence 1, R. I.

Helpful Data on Hydrants

64. Specifications for standard AWWA fire hydrants with helpful instructions for ordering, installing, repairing, lengthening and using. Issued by M. & H. Valve & Fittings Co., Dept. P.W., Anniston, Ala.

Cast Iron Pipe and Fittings For Every Need

65. Cast iron pipe and fittings for water, gas, sewer and industrial service. Super-deLavaud centrifugally-cast and pit-cast pipe. Bell-and-spigot, U. S. Joint, flanged or flexible joints can be furnished to suit requirements. Write U. S. Pipe and Foundry Co., Dept. PW, Burlington, N. J.

Job Data Offered on New Steel Water Lines

80. An 8-page illustrated report listing pipe diameters, pipe wall thicknesses, line pressures, coatings, engineering personnel, etc., is entitled "A Report of Dresser-Coupled Steel Water Lines in the Year 1947." A copy will be sent by Dresser Mfg. Div., 59 Fisher Ave., Bradford, Pa.

How to Estimate Quantity Of Joint Compound Needed

87. The uses of Tegul-Mineralead for bell and spigot pipe and G-K Sewer joint compound are described in bulletins issued by Atlas Mineral Products Co., Mertztown, Pa. Includes useful tables for estimating quantities needed.

Flow Meters With Many New Features

91. The new Propelflo meter for main-line metering introduces many new features you will want to look into. Send for latest bulletin today. Builders Providence, Inc., 16 Codding St., Providence 1, R. I.

All of These Booklets Are FREE and Many Are of Great Value. To Order Those You Need in Your Work Use the Coupon on Page 93.

Solve Corrosion Problems With This Special Alloy

41. "Everdur Metal" is title of an 8-page illustrated booklet describing advantages of this corrosion-resisting alloy for sewage treatment equipment, reservoir, and waterworks service. Dept. P.W., the American Brass Co., 25 Broadway, N. Y. C.

Eliminate Taste and Odor From Your Water

53. Technical pub. No. P.W. 213 issued by Wallace & Tiernan Co., Inc., Newark 1, N. J., describes in detail taste and odor control of water with Break-Point Chlorination. Send free to any operator requesting it.

Have You a Water Conditioning Problem?

56. Installation-tested equipment for complete municipal and industrial systems or individual units. Illustrated and described in latest booklets from Dept. P.W., American Wells Works, Aurora, Ill.

Quick Way to Locate Leaks and Pipe

57. Leak Locators. Again available to waterworks superintendents, the Globe line of leak locators, dipping needles and pipe finders. Several leaflets describing the orig-

Tested Jointing Materials

102. "Hydrotite" is a self-caulking, self-sealing joint compound for bell and spigot pipes. For data book and sample write Hydraulic Development Corp., 50 Church St., New York, N. Y.

Pipe That Is Immune to Tuberculation and Corrosion

104. Transite Pipe. The high strength and low weight of pipe moulded under pressure from asbestos fibre and cement, together with its immunity to tuberculation and corrosion is the subject of a 32-page pamphlet. Johns-Manville, Box 290, New York 16, N. Y.

Well Water Systems Built to Last

105. Layne pumps are built for wells ranging from 4" to 30" diameter and in capacities from 50 to 16,000 gpm. Full engineering data and many installation views are given in 32 page Pump Bulletin 4-42. Layne and Bowler, Inc., Memphis, Tenn.

Pressure Pipe That Retains Capacity

106. Several bulletins describing the construction of pressure pipe, list of installations, carrying capacity tests, making service connections under pressure; and detail descriptions of several installations. Lock Joint Pipe Co., P.O. Box 269, East Orange.

Full Data on Method and Results Of Water Main Cleaning

107. Water main cleaning by the National Method is title of 4-page folder describing methods and results obtained, with full data. National Water Main Cleaning Co., 30 Church St., New York 7, N. Y.

How About Centrifugal Pumps?

108. Centrifugal Pumps of various designs—single-stage, double-suction, split casing; single-stage single-suction; two-stage opposed impeller; three-stage; high-pressure; fire pumps; close-coupled. A bulletin for each type. Write to Dept. P.W., Peerless Pump Div., Food Machinery and Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.

Rapid Sand and Pressure Filter Data

109. Rapid sand filters. A complete line of vertical and horizontal pressure filters, wooden gravity filters, and filter tables and other equipment. For engineering data, write Roberts Filter Manufacturing Co., 640 Columbia Ave., Darby, Pa.

Specs for Gate Valves

112. Rigidly inspected gate valves for pressures up to 175 lbs. by R. D. Wood Co. Sizes 2" to 30"; for any standard type joint. R. D. Wood Co., Public Ledger Bldg., Philadelphia 5, Pa.

Handy Catalog Describes Small Hydrants, Drinking Fountains

115. This 44-page catalog describes ¾" to 2" hydrants. Also street washers, drinking fountains and other water service devices. The Murdock Mfg. & Supply Co., 426 Plum Street, Cincinnati 2, Ohio.

Get This Data for Your Laboratory

119. "Water and Sewage Analysis," a 32-page booklet, describes and illustrates equipment for making convenient and accurate water and sewage analyses, including comparators, aqua testers and turbidimeters. Hellige, Inc., 3718 Northern Blvd., Long Island City 1, N. Y.

Rust Wastes Your Money

121. You'll want data on the all-purpose anti-rust coating that can be brushed or sprayed on all metal surfaces, even those already attacked by rust. For full information on this firm, elastic coating write Rust-Oleum Corp., 2443 Oakton St., Evanston, Ill.

Do You Ever Have Leaks to Fix?

124. You'll want to know about the full line of "Skinner-Seal" clamps for repairing bell and socket joint leaks and broken mains. Step-by-step procedures are illustrated in catalog 41, a handsome 40-page presentation which shows applications of all fittings. Write M. B. Skinner Co., Dept. PW, South Bend 21, Ind.

Be Sure You Know How Much You Pump

125. Sparling Main-Line water meters are suited for your metering needs at pumping station and treatment plant. Recording, automatic and remote control units are described in bulletin 310. R. W. Sparling, Box 3277, Los Angeles, Calif.

The Modern Way to Filter Swimming Pool Water

129. That's the title of a bulletin full of facts about Bowsers' new diatomite filter to produce clear, sparkling, clean water at low cost. Occupies small space, doesn't waste water. Gives sizes to use, performance charts, etc. Write Bowser, Inc., Dept. PW, 1395 Creighton Ave., Ft. Wayne, Ind.

All About Cement-Mortar Lining of Water Mains

133. Here, in a really beautiful booklet, is practically everything you need to know about this method of lining mains in place—the needs, methods, and results that will interest you. Centriline Corp., Dept. PW, 140 Cedar St., New York 6, N. Y.

How Elevated Water Tanks Can Save on Operating Costs

134. Beautiful new booklet on Horton elevated steel water tanks suggests ways to reduce pumping costs, increase capacity of systems, maintain uniform pressure, etc. Illustrates 7 models of welded, ellipsoidal-bottom, elevated steel tanks in full color. Write Chicago Bridge & Iron Co., 2115 McCormick Bldg., Chicago 4.

Here's Data on All Swimming Pool Needs

135. Well illustrated bulletin describes filters, water softeners, hydrogen ion plants, chlorine feeders and complete equipment for swimming pools etc. Copy sent on request by Dept. PW, Chemical Equipment Co., 223 Center St., Los Angeles 54, Calif.

Paint for Protection And Good Appearance

144. An 8-page bulletin describes 14 different uses for "Inertol" products in water works for protecting and waterproofing concrete, steel and wood structures. Get data on these paints and enamels from Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N. J.

Faster Pipe Laying With Precaulked and Threaded Joints

148. McWane 2" cast iron water pipe with threaded joints and precaulked bell and spigot pipe are described in folder WM-47. Additional data on 3" to 12" centrifugally cast pipe and fittings in folder WL-47, both issued by McWane Cast Iron Pipe Co., Birmingham 2, Ala.

How to Use Alum For Coagulation

152. Alum for coagulation in both water and sewage treatment plants is the subject of literature now available from Dept. PW, General Chemical Division, 40 Rector Street, New York 6, N. Y.

When you need special information—consult the READERS' SERVICE DEPT. on pages 93-97

NEWS OF ENGINEERS

Leonard W. Trager, Director of Sanitary Engineering for New Hampshire, has been appointed by the Public Health Service to head the New England Drainage Basins office of the Division of Water Pollution. Mr. Trager served in the Sanitary Corps during World War II, in this country, in the Mediterranean and in the European Theater.

John R. Purser, Jr., of Purser & London, Builders-Providence, Omega and Proportioneers representative in the Carolinas has received a silver pin representing ten years of service with these companies.

Sol Pincus, well-known and highly regarded sanitary engineer, has been appointed to head the Environmental Sanitation Section of the World Health Organization. He left early in April for Geneva, Swtzerland, which will be headquarters.

Robert K. Horton has been appointed a sanitary engineer on the staff of the Ohio River Valley Water Sanitation Commission. Mr. Horton was a Lt. Col. in the Sanitary Corps and served with the Institute of Inter-American Affairs.

Clifford L. Morgan has become associated with Dana E. Kepner of Denver, Colo., manufacturers' representative and agent. Mr. Morgan before the war was with Whitman, Requardt & Smith; and during the war served in the Sanitary Corps.

Chester E. Albright, formerly president of Albright & Friel, consulting engineers of Philadelphia, Pa., died on March 29. He had been continuously in the private practice of engineering for 55 years.

ENGINEERS NEEDED

Executive Director for the Community Redevelopment Agency of the City of Los Angeles. Salary $11,-280 per year; desirable qualifications: graduation from college with engineering or other suitable degree and eight years of experience in governmental planning and development or subdivision work. Last day for filing is May 31. Write Community Redevelopment Agency, Box 2316 Terminal Annex, Los Angeles 54, Calif.

U. S. Pipe Reduces Price of Cast Iron Pipe

The United States Pipe & Foundry Co., Burlington, N. J., has announced a general reduction of $7 per ton on cast iron pipe and fittings, effective April 25; and a further reduction of $4 per ton effective May 1.